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HARTLEY BRIDGE

Hartley Bridge Structural Investigation & Assessment

Stage 2 Assessment Report

DRAFT ISSUE 1 | AUGUST 2017

ROUGHAN & O'DONOVAN

HARTLEY BRIDGE STRUCTURAL INVESTIGATION AND ASSESSMENT

Hartley Bridge

STAGE 2 ASSESSMENT REPORT

Document No:.................................. 16.181.10 – DL-LP2784-001

Made:... S Harper

Checked:.. P King

Approved: .... J Kelly

Document No. / Description	Issue	Made	Checked	Approved	Date
Hartley Bridge Assessment Report	Draft Issue 1	SH	PK	JK	August 2017

HARTLEY BRIDGE STRUCTURAL INVESTIGATION AND ASSESSMENT
Hartley Bridge
STAGE 2 ASSESSMENT REPORT

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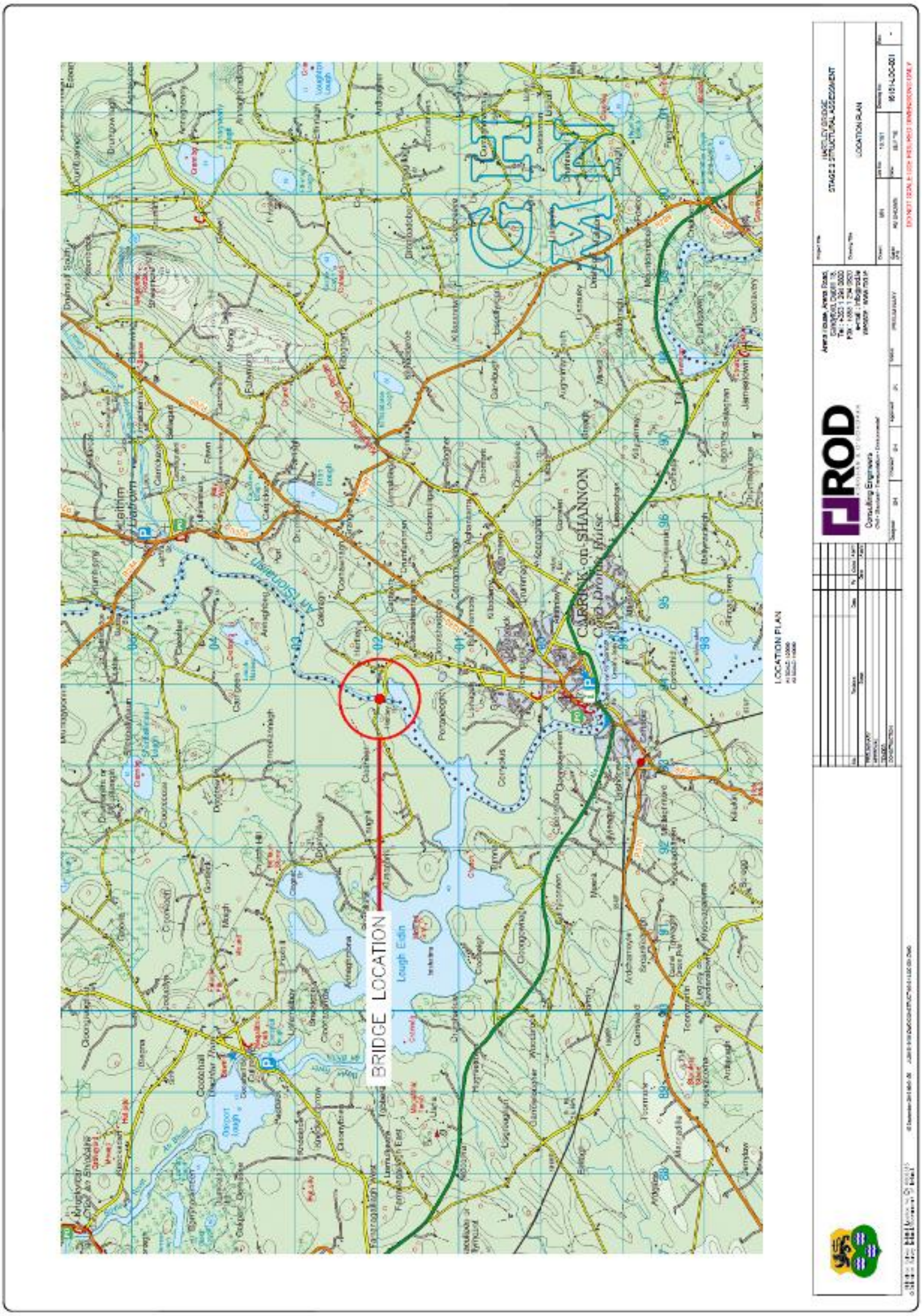
1. LOCATION MAP



2. INTRODUCTION

Roughan & O'Donovan Consulting Engineers (ROD) has been appointed by Leitrim County Council (LCC) to undertake the detailed inspection, structural investigation and assessment of the 8-span, concrete beam and slab, Hartley Bridge in Co. Leitrim. Hartley Bridge is located approximately 2km north of Carrick on Shannon and situated in the townland of Hartley on the border between Co Leitrim and Co Roscommon. The bridge was constructed in 1915 and was previously inspected and assessed by ESB in 1984 and later again by Doran Consulting in January 2016. As a result of these assessments a height restriction of 2.5m is currently in place on the bridge.

This report summarises the findings of the Stage 2 Structural Assessment of Hartley Bridge. It further progresses the two previous assessments carried out by ESB and Doran Consulting in 1984 and 2016 respectively.

An additional inspection for assessment of the current condition of the bridge was carried out by Mr Peter King of ROD on 18th and 19th of April 2017, as well as a structural investigation carried out by BHP Laboratories at the same time, of which the factual report is enclosed as Appendix D of this report.

3. DESCRIPTION OF STRUCTURE AND PHYSICAL ASSESSMENT

Hartley Bridge (LM-LP3400-001.00) carries a single track County Road (LP3400) across the River Shannon on the border between Co Leitrim and Co Roscommon. The bridge consists of six fully integral spans ranging from approximately 7.20m to 12.35m, and two smaller approach spans at the west end of the bridge which form an integral structure in themselves but are structurally separate of the main spans. These spans (Spans 7 and 8) measure 3.63m and 3.68m respectively.

The overall length and width of the bridge is 72.05m and 5.84m, respectively. The main structural support in each span is provided by two longitudinally spanning reinforced concrete parapet beams approximately 1.725m deep, which are fully integral with the sub-structure. Reinforced concrete transverse beams span between the parapet beams over which a reinforced concrete slab forms the deck of the bridge and supports the road construction.

The sub-structure consists of reinforced concrete abutments at both the west and east ends of the bridge and reinforced concrete columns with diagonal bracing and horizontal ties form the piers.

The bridge carries one lane (approximately 3.97m between soft verges) of traffic. The longitudinal spanning beams form the containment for the bridge and measure approximately 1.2m in height above the carriageway.

The findings of the previous Inspections for Assessment indicated that there is extensive spalling of the concrete and many areas of exposed and corroded steel reinforcement.

The assessment carried out previously concluded that the bridge failed the 40 tonne Assessment loading and recommends that a Stage 2 Assessment be carried out to further determine the safe load carrying capacity of the bridge.

The previous assessments give geometric details of the bridge superstructure of spans 1 to 6, however the source of this information is not mentioned. Additionally no assessment has previously been carried out on spans 7 and 8 (measuring 3.64m) and no information on the structural arrangement is given.

An inspection of the bridge was carried out by ROD in April 2017 and structural testing of the bridge at the same time. This inspection and investigation provided information regarding the concrete and steel reinforcement characteristics and the geometric arrangement within the bridge structure. This data was used to confirm the dimensions and material properties to be used in this structural assessment. Chemical and electrochemical testing was also carried out in order to determine possible causes for the observed spalling to the soffit of bridge deck and beams.

Photographs taken during the inspection showing the current condition of the bridge have been included in Appendix A. The assessment calculations and structure general arrangement drawing have been included in Appendices B and C, respectively.

4. VISUAL INSPECTION OF STRUCTURE

An inspection for assessment of the current condition of the bridge was carried out by Mr Peter King of ROD on 18th and 19th of April 2017. Weather conditions were dry at the time of the inspection with an ambient temperature of approx. 13 degrees Celsius on both days. The inspection consisted of visual observations, a detailed photographic record and a dimensional survey of all accessible elements of the structure. As mentioned above, the visual inspection was carried out in tandem with the structural investigation works carried out by BHP Ltd. and therefore an underbridge access vehicle was on-hand to facilitate access to the underside of the bridge. Unfortunately, due to technical difficulties relating to the steep gradient over the bridge, the underbridge unit could only deploy over span 3 which is relatively flat as it forms the crown of the bridge. The soffits of all other spans and piers were inspected from a distance from the underbridge unit positioned under span 3 and from the riverbanks. Spans 7 and 8 were dry at the time of inspection.

The bridge surfacing was found to be in fair condition but exhibited some degree of wear and loss of surface texture, particularly along wheel tracks. As expected, the most significant wear was noted at the steeper sections of the bridge which are more prone to traction forces. The level of deterioration does not appear to affect road user safety at this time and therefore does not warrant immediate replacement. However, it is recommended that resurfacing of the bridge deck be included in any proposed remedial scheme. Most significantly, there was no evidence of significant cracking or damage to the surfacing that could be indicative of structural distress in the bridge superstructure or substructure.

The reinforced concrete parapets are also the main longitudinal beams and therefore are discussed in more detail in that capacity in the paragraphs below. With regard to their vehicle containment function, the parapets appear to be adequate for the observed road speeds. However, this is based on visual observations only as no assessment calculations were carried out to determine their vehicle containment capacity. Numerous locations of exposed reinforcement (shear link steel straps) were noted to the inside and outside faces of the parapets and in a small number of instances, significant corrosion with section loss was evident on the straps. This appears to be due to insufficient concrete cover. In general, the extent of corrosion appears minimal and the exposed area is relatively small, and therefore this defect is not considered to be structurally significant at this time. However, concrete repairs are recommended to prevent further deterioration. There are no safety barriers provided on the western approach and the safety barriers on the eastern approach are in very poor condition and do not comply with current standards. The installation of a compliant safety barrier system should be considered as part of any proposed remedial works. There are no footways across the structure and no raised concrete verges (rubbing strips) are provided. Grassed verges have formed on the road surfacing along the face of both parapets.

The bridge reinforced concrete deck soffit and beams were inspected from the underbridge unit and riverbanks and were found to be in poor condition. As noted during previous inspections, there is widespread spalling with exposed reinforcement evident throughout the soffit of the bridge deck, longitudinal beams and transverse beams. Significant spalling was also noted to the sides of the beams below deck level. The exposed reinforcement exhibits corrosion with loss of section and lamination of steel flanges noted in some locations. Based on the record information made available, the spalling appears to have progressed over a relatively long period of time. However, no direct comparison was possible to determine the rate of deterioration.

Most significantly, there was no evidence of structural distress in the bridge deck due to overload. Close inspection of the parapets (which also constitute the main longitudinal girders) did not reveal any cracking over the piers (locations of max. hogging moment). Similarly, there is no well-defined cracking pattern in the soffit or sides of the longitudinal or transverse beams at midspan. The extent of spalling, cracking and delaminated concrete is no more pronounced at these locations of high stress than elsewhere on the deck, indicating that the observed deterioration is due to poor quality concrete, lack of concrete cover and/or poor workmanship rather than overload or a loss of structural capacity due to corrosion. Corrosion due to atmospheric carbon dioxide may also be a contributory factor in spans 7 and 8 where relatively high depths of carbonation were identified (up to 24mm deep, concrete cover is less than 20mm in some locations). Nonetheless, the widespread nature of the spalling indicates the bridge deck is nearing the end of its serviceable life. Significant remedial works are required to address the existing defects and an onerous inspection and maintenance regime will be required going forward in order to maintain the deck in a serviceable condition.

2 no. slit trenches on the bridge surface facilitated inspection of the top surface of the bridge deck at these locations. The slit trenches revealed that the deck is not waterproofed and the trench at the west end of the bridge exposed a layer of granular fill above the deck. The concrete deck appeared to be in relatively good condition with no evidence of deterioration in the form of cracking or spalling. However, it should be noted that the two locations inspected constitute a very small sample area of the bridge deck as a whole.

The reinforced concrete piers and abutments are in relatively good condition but also exhibit spalling with exposed reinforcement in numerous locations. As per the bridge deck/beams, there is no evidence to suggest that the observed defects are indicative of structural distress due to overload. However, the defects noted do pose a durability issue and will require concrete repairs as part of any proposed remedial works.

No information on the foundation type is currently available and no scour inspection was carried out as part of the inspection. There is currently no evidence of cracking or differential settlement in the substructure that could be indicative of undermining due to scour. However, given the age of the structure, the extent of concrete deterioration evident elsewhere on the structure and the lack of information on the foundation type, it is recommended that a scour inspection is carried out in accordance with BD 97/12.

5. REVIEW OF PREVIOUS ASSESSMENT OF STRUCTURE

6.1 Previous Reports

Previous studies carried out at this structure relevant to this assessment are listed below. The results and findings of these studies have been considered in this report.

- Hartley Bridge, Structural Report, Electricity Supply Board (ESB), Civil Works Department, May 1984.
- Stage 1 Structural Assessment Report, Hartley Bridge, Doran Consulting, January 2016.

6.2 Basis of Previous Assessment

6.2.1 ESB Structural Assessment

The first structural assessment of Hartley Bridge was carried out in May 1984 by ESB including material testing of the concrete and the steel.

A summary of the concrete core test results is summarised in Table 1 below.

Table 1: Concrete Core Compressive Strength Test Results

Diameter (mm)	Length (mm)	Density (kg/m^3)	Cube Strength (N/mm^2)
150	310	2415	31.5
150	310	2400	31.5
150	261	2405	57.5

A summary of the steel tensile tests is summarised in Table 2 below.

Table 2: Steel Tensile Test Results

Specimen Ref.	Upper Yield Stress (N/mm^2)	Tensile Strength (N/mm^2)	% Elongation
A	291	430	43
B	256	359	43
C	300	408	29
D1	249	412	29
D2	267	450	30

The structural geometry of the bridge and the reinforcement arrangement was determined by a structural survey of the bridge. A summary of the geometrical, material assumptions are shown below in Table 3.

Table 3: Structural Assessment Data

Attribute	Hartley Bridge
Span Geometry	
Total length	72.05m
Span lengths:	
Span 1	7.00m
Span 2	10.37m
Span 3	11.82m
Span 4	10.41m
Span 5	10.39m
Span 6	10.39m
Span 7	3.63m
Span 8	3.68m
Overall bridge width	5.84m
Carriageway width	3.97m
Structural Arrangement	
Parapet beams	
Section	1778mm x 305mm
Reinforcement (bottom)	3 No. Moss bars 3No. 25mm dia. bars 1 No. 22mm dia. bar
Reinforcement (top) mid-span	2 No. Moss bars 2No. 22mm dia. bars
Reinforcement (top) at supports	2 No. Moss bars
Transverse deck beam	
Section	203mm x 127mm
Reinforcement (bottom)	2No. Moss bars 1 No. 25mm dia. bar
Deck slab	
Section	152mm deep
Reinforcement (bottom)	12.7mm dia. bars at 121mm spacing
Reinforcement (top)	12.7mm dia. bars at 241mm centres
Columns	
Section	381mm x 457mm
Reinforcement	6 No. 19.1mm dia. bars 4.71mm links at 150mm centres
Diagonal brace	
Section	305mm x 254mm
Reinforcement	4 No. 12mm dia. bars 4.7mm links at 225mm centres
Horizontal Tie	
Section	254mm x 254mm

Attribute	Hartley Bridge
Reinforcement	4 No. 12mm dia. bars 4.7mm links at 225mm centres
Construction Materials	
Concrete compressive strength	25 N/mm^2
Reinforcement yield strength	250 N/mm^2

The structural assessment incorporated hand calculations in accordance with CP 110: Code of Practice for the structural use of concrete for the determination of the structural capacity of the reinforcement concrete elements.

The structural assessment carried out by ESB recommended that the bridge be subject to a 5 tonne weight restriction.

6.2.2 Doran Consulting Structural Assessment

The assessment carried out by Doran Consulting in January 2016 included a site inspection; however no structural investigation was carried out and as such the assumptions for the material properties were the same as for the ESB assessment.

This assessment incorporated hand calculations in accordance with BD 21 to determine the load carrying capacity of the structure. The assessment was limited to spans 1 to 6 as no information on spans 7 and 8 was available.

The assumptions made for the geometry of the reinforcement elements and the reinforcement arrangement were the same as were considered for the ESB assessment shown above. Due to the condition of the structure, the Doran assessment assumed a Condition Factor of 0.8 for the determination of the load carrying capacity of the structural elements.

A summary of the assumptions for the loading in accordance with BD 21 are shown below in Table 4.

Table 4: Assessment Loading Data

Attribute	Hartley Bridge
Loading Parameters	
Notional lane width	3.65m
40 tonne assessment loading	UDL & KEL (BD 21/14)
HGV Hourly flow	Low
Road condition	Good

A summary of the assessment results presented in the Doran assessment report for 40T HA loading are shown in Table 5 below. Where the 40T Assessment Rating is greater than 1 this indicates a non-compliance with the codes of practice and standards and a reduction in the required factors of safety applied to the element under consideration.

Table 5: Overstress Summary

ELEMENT	Load Case Combination	Failure Mode and Overstress	
		Failure Mode	40T Assessment Rating
Deck slab	Single Wheel	Bending hogging	3.97
		Bending sagging	2.02
		Shear	1.34
Transverse beams	UDL+KEL	Bending sagging	2.60
		Shear	2.90
	Single axle	Bending sagging	3.12
		Shear	3.90
Parapet beam	UDL+KEL	Bending sagging	0.36
		Bending hogging	1.19
		Shear	2.44
	Single Axle	Bending sagging	0.39
		Bending hogging	1.23
		Shear	2.77
Columns	UDL+KEL	Combined moment & axial	1.41
Diagonal Brace	UDL+KEL	Combined moment & axial	1.19
Horizontal Tie	UDL+KEL	Axial	0.81

A summary of the conclusions from the Doran assessment are as follows:

- The parapet beam, transverse beams, deck slab, columns and diagonal bracing all fail the 40T Assessment Loading for HA and are given a load rating of less than 3T.
- The existing parapet beams do not comply with the current guidelines for vehicle containment.
- The abutments were assessed qualitatively and considered to be adequate.

6. STAGE 2 ASSESSMENT OF STRUCTURE

6.1 Basis of Assessment

The structural assessment has been carried out based on the following documents from Volume 3 Highway Structures: Inspection and Maintenance of the Transport Infrastructure Ireland (TII) Design Manual for Roads and Bridges:

(i) Departmental Standard AM-STR-06026 (NRA BD 21/14), "The Assessment of Road Bridges and Structures".

(ii) Departmental Advice Note AM-STR-06002 (NRA BA 16/14), "The Assessment of Road Bridges and Structures ".

(iii) Department Standard AM-STR-06031 (NRA BD 44/14), "The Assessment of Concrete Highway Bridges and Structures".

(iv) Department advice note AM-STR-06010 (NRA BA 44/14), "The Assessment of Concrete Road Bridges and Structures".

(v) Departmental Standard AM-STR-06015 (NRA BA 55/14), "The Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures".

(vi) Departmental Standard DN-STR-03011 (NRA BD 52/16), "The Design of Road Bridge Parapets".

(vii) Departmental Standard AM-STR-06030 (NRA BD 37/14) "Loads for Highway Bridges".

(viii) Departmental Standard AM-STR-06042 "Structural Review and Assessment of Road Structures".

In addition, the following technical documents have been used to assess the adequacy of the structure and the parapet:

(ix) British Standard BS 5400 Part 4: 2000, "Steel, Concrete and Composite Bridges – Part 4: Code of practice for design of concrete bridges".

(x) British Standard BS 6779 Part 4: 1999, "Highway Parapets for Bridges and Other Structure – Part 4: Specification for parapets of reinforced and unreinforced masonry construction".

6.2 Structure Geometry

The structural dimensions and material properties listed in Table 6 were obtained during the inspection and investigation and provided by BHP Laboratories in July 2017 in the factual report included in Appendix D and have been used for the current Stage 2 Assessment. In general, the structural arrangement is similar to that determined by ESBI and Doran consulting. T he only significant changes relate to a reduction in the amount of steel in the main longitudinal beams (parapet beams) and transverse beams, and the discovery of shear reinforcement in the form of steel straps in the beams.

Table 6: Structural Investigations Data

Attribute	Hartley Bridge
Span Geometry	
Total length	72.05m
Span lengths:	
Span 1	7.00m
Span 2	10.37m
Span 3	11.82m
Span 4	10.41m
Span 5	10.39m
Span 6	10.39m
Span 7	3.63m
Span 8	3.68m
Overall bridge width	5.84m
Carriageway width	3.97m
Deck Make-up	
Surfacing	70mm deep (throughout)
General fill (cobbles, gravel, sand)	230mm deep (for spans 6,7 & 8 0 mm for all other spans)

Attribute	Hartley Bridge
Structural Arrangement	
Parapet beams	
Section	1725mm x 320mm
Reinforcement (bottom)	2 No. Moss bars
Reinforcement (top)	1 No. Moss bars 2No. 16mm dia. bars
Shear reinforcement	25 mm wide 4mm thick vertical and inclined steel straps at 315 mm and 220 mm centres respectively
Transverse deck beams over piers	
Section	225mm x 127mm
Reinforcement (bottom)	2No. Moss bars 2 No. 20mm dia. bar
Transverse deck beam mid-span	
Section	200mm x 127mm
Reinforcement (bottom)	2No. Moss bars
Deck slab	
Section	152mm deep
Reinforcement (bottom)	12.7mm dia. bars at 110mm spacing
Reinforcement (top)	12.7mm dia. bars at 215mm centres
Columns	
Section	381mm x 457mm
Reinforcement	6 No. 19.1mm dia. bars 4.71mm links at 150mm centres
Diagonal brace	
Section	305mm x 254mm
Reinforcement	4 No. 12mm dia. bars 4.7mm links at 225mm centres
Horizontal Tie	
Section	254mm x 254mm
Reinforcement	4 No. 12mm dia. bars 4.7mm links at 225mm centres
Moss bars (reinforcement for parapet edge beams and transverse beams)	
Top flange	25 mm wide x 9mm thick
Web	85 mm deep x 9mm thick
Bottom flange	65 mm wide x 9 mm thick

6.3 Assessment Loading

The applied dead and superimposed dead loads due to the structural concrete, parapet and carriageway surfacing were calculated from the suggested material properties given in the appropriate standards and codes of practice, records of the previous structural inspection and measurements obtained on site.

The Stage 2 Assessment has considered full HA loading (consisting of a uniformly distributed load UDL and a knife edge load, KEL = 120kN) determined in accordance with NRA BD 21/14. All loading was factored using the appropriate values from NRA BD 21/14 and NRA BD 44/14.

The loaded length for the HA (UDL) and the position of the KEL were selected to produce the most onerous effects of shear and bending moment within the structure, for whichever attribute and location was being assessed. Live load was combined with fill depth, surfacing depth and superimposed loads in accordance with load factors from BD 21/01.

For determining local load effects for the deck slab and transverse beams, single axle and single wheel loads were applied separately as different load cases to the UDL and KEL in accordance with NRA BD 21/14. The position of the single wheel loads were selected to produce the most onerous effects of shear and bending moment within the structure.

6.4 Material Properties

The material properties of the bridge structural elements, overlaying fill and surfacing have been based on the laboratory test results and on the recommendations of NRA BD 21/14 Chapter 4 "Properties of Materials". Concrete cores extracted by BHP Laboratories and a section of the reinforcing steel were tested for compressive strength and yield strength respectively. Results have been used in accordance with NRA BD 44/14 and NRA BA 44/14 to calculate the strength of the in-situ concrete and steel for the structural assessment.

Material properties obtained from laboratory testing carried out by BHP Laboratories are presented in the factual report included in Appendix D and those obtained from the ESB investigation are presented in section 4.2. The following material properties have used during the Stage 2 Assessment and have been determined by calculating the Worst Credible Strength in accordance with NRA BA 44/14 and using all of the laboratory testing available:

Concrete strength	=	36 N/mm^2	
Steel yield stress	=	250 N/mm^2	
Concrete Modulus of Elasticity	=	14000 N/mm^2	
Steel Modulus of Elasticity	=	205000 N/mm^2	
Plain Concrete Unit Weight	=	2412.5 kg/m^3	(23.67 kN/m^3)
Steel Unit Weight	=	7850 kg/m^3	(77 kN/m^3)
Fill Material Unit Weight	=	2200 kg/m^3	(21.6 kN/m^3)

For concrete strength, the value of the material factor applied is the worst credible strength ($\gamma mc = 1.20$). For steel reinforcement, the value of the material factor was taken in accordance with Table 4A of NRA BD 44/14 for Worst Credible Strength where measured steel depths are used ($\gamma ms = 1.05$).

6.5 Assumptions

The following assumptions have been made in the accompanying assessment calculations:

- The foundations of the bridge are assumed to be adequate and are subject to inspection and investigation for scour;
- The Reduction Factor applied to the assessment live loading was taken for Low Traffic Good Surface (BD 21/01, Figure 5.4) as the road surface does not show any excessive signs of deterioration.
- A condition factor of 0.9 has been considered in the calculation of member capacities in accordance with clause 3.19 of BD 21. This factor takes account of localised section loss in the steel reinforcement due to corrosion.

6.6 Method of Analysis

6.6.1 Bridge Model

Hartley Bridge has been modelled three dimensionally using the program MIDAS Civil 2015, with each of the main structural elements of the bridge being represented by a beam element. The section properties of each structural element have been calculated by the program based on the member section geometry. A screenshot of the 3D model in MIDAS is included in Appendix B.

The foundations of each of the bridge's columns has been assumed as pad footings and modelled in the analysis as a pin support, allowing full rotation in all directions. The ends of the bridge have been modelled as fully fixed as there is no evidence of any bearings to allow for any expansion or rotation at the abutments.

The 3D model in MIDAS has been used to determine the load effects for the parapet beams, columns, diagonal braces and tie beams. For the transverse beams and slab, hand calculations have been implemented to determine the local effects from single axle loads.

The results of the detailed deck structural assessment calculations are included in Appendix B.

6.6.2 Deck and transverse beams

In order to determine the most onerous load effects for the deck slab and the transverse beams in the bridge, hand calculations have been produced to analyse the deck and transverse beams for local effects by applying single axle and single wheel loads. These calculations are included in Appendix B.

6.6.3 Abutments and Wingwalls

A quantitative assessment of the abutments, piers, and wingwalls was not carried out as part of this assessment. These bridge elements have been assessed qualitatively by considering the condition of the structure and the significance of any defects, observed during the bridge inspection, in accordance with the "Sub-structure, foundations and walls" clauses of Chapter 8 of BD 21/14.

7. STAGE 2 ASSESSMENT RESULTS

7.1 Superstructure

The quantitative assessment results are presented as a Stress Index, which is the ratio of calculated assessment load effect [SA*] to the respective assessment resistance [RA*]. A Stress Index of 1.0 or less indicates full compliance with the standard. If the combination of loading and capacity occurs in service such that the Stress Index exceeds unity, this indicates a reduction in the safety factors inherent in the Codes of Practice or Standards. The implications of such a reduction would be individually assessed with regard to the safety of the structure.

The results all include for the application of a K-factor for Low Traffic Good Surface, as determined above in Section 5.5.

7.2 Deck Slab

Table 7: Summary of Stress Indices for the Deck Slab

Structural Element	HA Assessment Loading	Stress Index in Bending	Stress Index in Shear
Deck Slab Mid span	40 tonnes	1.62*	1.39*
	26 tonnes	1.62*	1.39*
	18 tonnes	1.62*	1.39*
	7.5 tonnes	**0.86***	**0.82***
	3 tonnes	**0.46***	**0.52***
	FE Group 1	1.03*	0.95*
	FE Group 2	**0.57***	**0.60***
Deck Slab at supports	40 tonnes	2.90*	1.39*
	26 tonnes	2.90*	1.39*
	18 tonnes	2.90*	1.39*
	7.5 tonnes	1.56*	0.82*
	3 tonnes	**0.83***	**0.52***
	FE Group 1	1.85*	0.95*
	FE Group 2	1.03*	0.60*

*Single axle wheel load critical

The results indicate that the deck slab can sustain the 7.5 tonnes HA and FE Group 2 assessment loading in sagging however is only capable of sustaining the 3 tonnes assessment loading in hogging. Therefore, the deck slab is given a load rating of 3 tonnes.

7.3 Transverse Beams

The structural investigation indicated that the transverse beams vary in geometry and reinforcement arrangement between the piers and throughout the spans and therefore the results for each type of beam are presented separately in tables and 8 and 9 respectively.

Table 8: Summary of Stress Indices for the Transverse Beams at the Piers

Structural Element	HA Assessment Loading	Stress Index in Bending	Stress Index in Shear
Transverse Beams (piers)	40 tonnes	1.55*	0.81*
	26 tonnes	1.55*	0.81*
	18 tonnes	1.55*	0.81*
	7.5 tonnes	**0.96***	**0.52***
	3 tonnes	**0.64***	**0.37***
	FE Group 1	1.09*	0.59*
	FE Group 2	**0.73***	**0.41***

*Single axle wheel load critical

Table 9: Summary of Stress Indices for the Transverse Beams in Spans

Structural Element	HA Assessment Loading	Stress Index in Bending	Stress Index in Shear
Transverse Beams (spans)	40 tonnes	1.93*	0.81*
	26 tonnes	1.93*	0.81*
	18 tonnes	1.93*	0.81*
	7.5 tonnes	1.19*	0.52*
	3 tonnes	**0.80***	**0.37***
	FE Group 1	1.35*	0.58*
	FE Group 2	**0.91***	**0.41***

*Single axle wheel load critical

The results indicate that all of the transverse beams can sustain the 3 tonnes HA and FE Group 2 assessment loading in bending and shear.

7.4 Parapet Beams

Table 10: Summary of Stress Indices for the Parapet Beams

Structural Element	HA Assessment Loading	Stress Index in Bending	Stress Index in Shear
Parapet beams Mid span	40 tonnes	1.02	1.17
	26 tonnes	1.01	1.16
	18 tonnes	0.86	1.04
	7.5 tonnes	**0.67**	**0.89**
	3 tonnes	**0.59**	**0.82**
	FE Group 1	0.82	1.01
	FE Group 2	**0.63**	**0.85**
Parapet beams at supports	40 tonnes	1.38	1.14
	26 tonnes	1.34	1.13
	18 tonnes	1.22	1.01
	7.5 tonnes	1.04	0.86
	3 tonnes	**0.95**	**0.79**

Structural Element	HA Assessment Loading	Stress Index in Bending	Stress Index in Shear
	FE Group 1	1.18	0.98
	FE Group 2	**0.99**	**0.82**

The results indicate that the parapet beams in sagging can carry the 7.5 tonnes HA and FE Group 2 assessment loading, however in the hogging at the supports they are only capable of withstanding the 3 tonnes HA assessment loading. Therefore, the parapet beams are given a load rating of 3 tonnes.

7.5 Columns

Table 11: Summary of Stress Indices for the Columns

Structural Element	HA Assessment Loading	Stress Index
Columns Max axial with co-existing bending	**40 tonnes**	**0.73**
	26 tonnes	**0.72**
	18 tonnes	**0.64**
	7.5 tonnes	**0.54**
	3 tonnes	**0.49**
	FE Group 1	**0.62**
	FE Group 2	**0.51**
Columns Max bending with co-existent axial	40 tonnes	1.00
	26 tonnes	**0.99**
	18 tonnes	**0.83**
	7.5 tonnes	**0.65**
	3 tonnes	**0.56**
	FE Group 1	**0.80**
	FE Group 2	**0.60**

The results indicate that the columns are can carry the 26 tonnes HA and FE Groups 1 & 2 assessment loading.

7.6 Diagonal Bracing

Table 12: Summary of Stress Indices for the Diagonal Brace

Structural Element	HA Assessment Loading	Stress Index
Diagonal brace Max axial with co-existing bending	**40 tonnes**	**0.68**
	26 tonnes	0.67
	18 tonnes	0.65
	7.5 tonnes	0.63
	3 tonnes	0.63
	FE Group 1	0.66
	FE Group 2	0.64
Diagonal brace Max bending with co-existent axial	**40 tonnes**	**0.87**
	26 tonnes	0.84
	18 tonnes	0.79

Structural Element	HA Assessment Loading	Stress Index
	7.5 tonnes	0.72
	3 tonnes	0.72
	FE Group 1	0.73
	FE Group 2	0.72

The results indicate that the diagonal braces can carry the full 40 tonnes HA assessment loading.

7.7 Horizontal Tie

Table 13: Summary of Stress Indices for the Horizontal Tie

Structural Element	HA Assessment Loading	Stress Index
Horizontal Tie	**40 tonnes**	**0.51**
	26 tonnes	0.39
	18 tonnes	0.37
	7.5 tonnes	0.34
	3 tonnes	0.34
	FE Group 1	0.35
	FE Group 2	0.34

The results indicate that the horizontal ties can carry the full 40 tonnes HA assessment loading.

7.8 Abutments, Pier and Wingwalls

In accordance with BD 21/14 a qualitative assessment may be carried out subject to the results of the visual inspection. Structural inspection showed that there were no signs of flexural cracking, rotation or differential settlement of the abutments or piers, which would be indicative of structural distress due either to overload, or movement of the substructure.

7.9 Overview

The results of the structural assessment indicate that all of the structural elements are capable of carrying at least the 3 tonnes assessment loading in accordance with NRA BD 21/14.

8. CONCLUSIONS

Structural Assessment

The results of the structural assessment indicate that the structure is capable of carrying 3 tonnes Assessment Live Loading in accordance with TII AM-STR-06026 (NRA BD 21/14). The more rigorous analysis carried out as part of this assessment and the discovery of shear reinforcement decreased the calculated level of overstress on most of the structural elements when compared to the assessment carried out by Doran Consulting in 2016, and consequently increased the permissible weight restriction level of the structure stated in Doran's report (< 3 tonnes);

Structural Investigation and Testing

The testing carried out as part of the structural investigation works indicated that the observed deterioration of the bridge deck concrete is not associated with the ingress of atmospheric carbon or chloride ion contamination of the concrete. The compressive strength testing determined average to good concrete with compressive strengths ranging from 31 to 47N/mm^2 (average for bridge deck = 46.4N/mm^2). The tensile testing carried out confirmed the presence of mild steel with yield strength of 271 MPa. The intrusive investigations verified the reinforcement details and revealed the presence of shear links in the form of mild steel straps at regular centres. The intrusive works also determined that the non-exposed reinforcement encased in concrete were visibly in good condition and free from corrosion when broken out;

Visual Inspection

With regard to the visual inspection, the most significant defects related to the concrete bridge deck, longitudinal and transverse beams. As noted during previous inspections, the deck soffit and beams exhibited widespread spalling with exposed reinforcement evident throughout the soffit of the bridge deck, longitudinal beams and transverse beams. However, there was no evidence of structural distress in the bridge deck due to overload. Close inspection of the parapets (which also constitute the main longitudinal girders) did not reveal any cracking over the piers (locations of max. hogging moment). Similarly, there is no well-defined cracking pattern in the soffit or sides of the longitudinal or transverse beams at midspan. The extent of spalling, cracking and delaminated concrete is no more pronounced at these locations of high stress than elsewhere on the deck, indicating that the observed deterioration is due to poor quality concrete, lack of concrete cover and/or poor workmanship rather than overload or a loss of structural capacity due to corrosion.

Nonetheless, the widespread nature of the spalling indicates that the bridge deck is nearing the end of its serviceable life with deterioration of fabric of the structure likely to accelerate in the short to medium term. As a result, the maintenance liability and associated cost are likely to increase over the remaining life of the structure. Significant remedial works are required to address the existing defects and an onerous inspection and maintenance regime will be required going forward in order to maintain the deck in a serviceable condition.

9. Recommendations

- The existing weight restriction should be maintained and stringently enforced. It is recommended that the existing height restriction barriers are maintained and supplemented with appropriate regulatory signage specifying a 3.0 tonne weight restriction over the bridge. The barriers and signage should be inspected on a regular basis;
- Based on the findings of the visual inspection, it is evident that the bridge is nearing the end of its serviceable life with deterioration of fabric of the structure likely to accelerate in the short to medium term. In light of this, it is recommended that a comprehensive inspection and maintenance regime is implemented to facilitate regular close inspection and monitoring of the deck soffit and repairs to any newly appeared spalling. In addition, provision should be made for replacing the structure in the short to medium term subject to the findings of an economic appraisal of the options.
- It is recommended that the following remedial works are carried out in order to slow the deterioration of the bridge deck and maintain the deck in a serviceable

condition:

- Breakout all loose/spalling/delaminating concrete, prepare surfaces and apply a corrosion inhibitor to the exposed steelwork to prevent further corrosion and associated loss of structural capacity. Concrete repairs could also be considered but may prove difficult to execute and not yield any significant improvement in durability. As a minimum, these repairs should be carried out to the deck soffit over the navigation spans to address the risk associated with falling concrete;
- Install an approved waterproofing system to the top surface of the deck slab and resurface the bridge and approaches;
- Install compliant safety barriers at all four corners of the bridge;

It should be noted that there are a number of logistical difficulties associated with the above works including:

- Upholding the 3 tonne weight restriction throughout the works;
- Given that the available underbridge unit is not able to deploy on the steeper areas of the deck, extensive scaffolding will be required to safely execute the works.
- A temporary closure of the navigation spans will be required;
- A temporary road closure will be required for the duration of the works;

- Given the age of the structure, the extent of concrete deterioration evident elsewhere on the structure, and the lack of information on the foundation type, it is recommended that a scour inspection is carried out in accordance with BD 97/12.

Appendix A
Photographs

Photograph 1: Bridge Approach (west)

Photograph 2: Bridge Surface (East End)

Photograph 3: Bridge elevation

Photograph 4: East Abutment

Photograph 5: Pier 2

Photograph 6: Piers 3 and 4

Photograph 7: Bridge Beam –Span 6

Photograph 8: Bridge Beam –Span 6

Photograph 9 Bridge Deck –Span 6

Photograph 10: Bridge Deck –Span 6

Photograph 11: Bridge Deck –Span 3

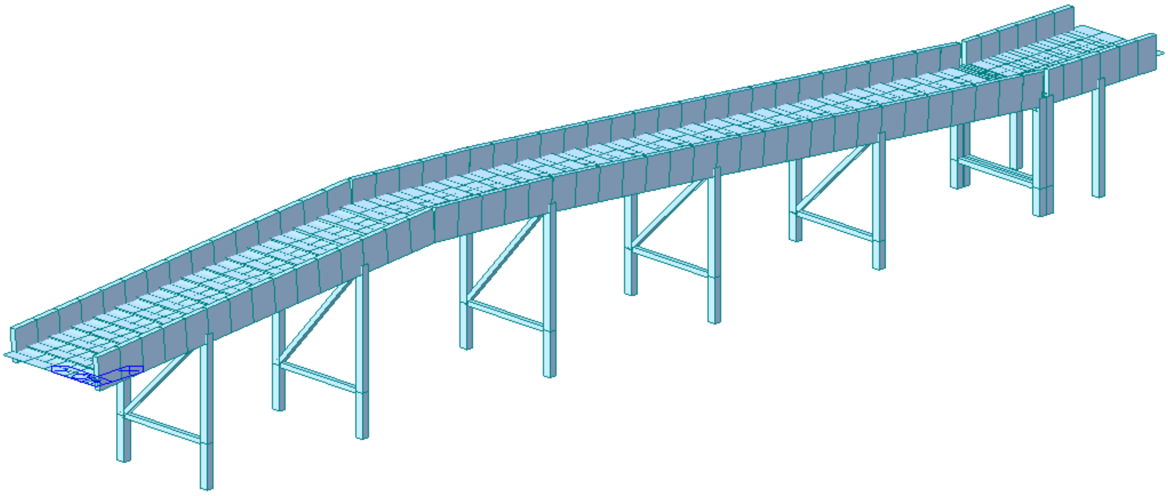
Photograph 12: Bridge Deck –Span 3

Photograph 13: Bridge Beam Span 3 / Pier 3 South

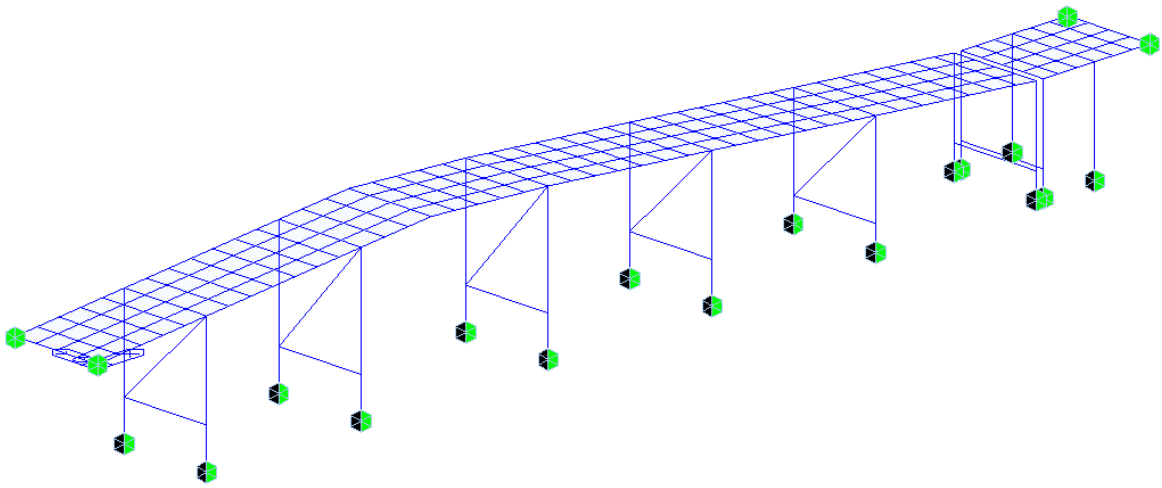
Photograph 14: Bridge Parapet / Main Longitudinal Beam (North)

Appendix B
Calculations

B.1. STRUCTURAL ANALYSIS



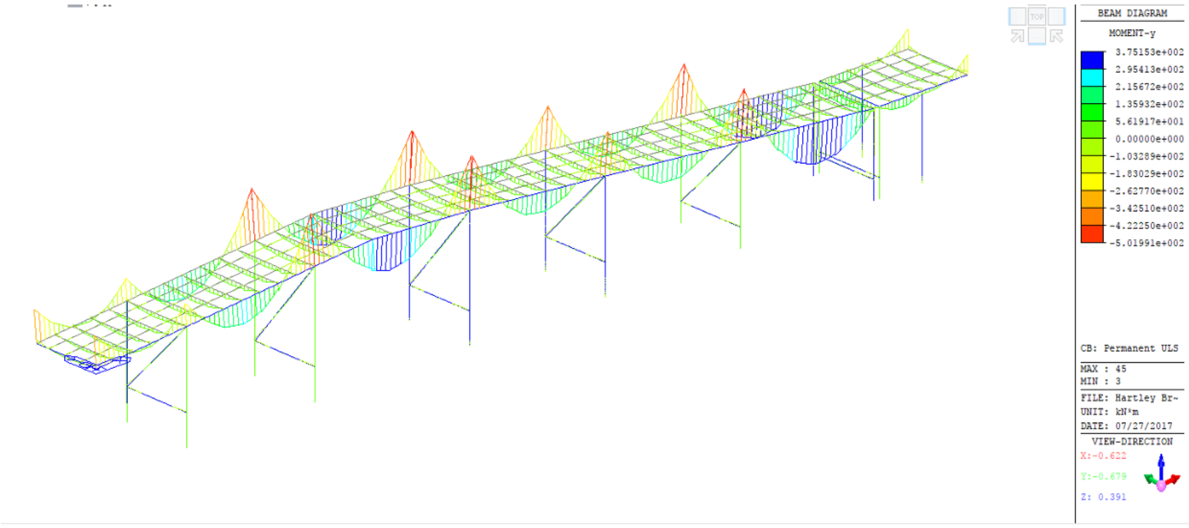
(a)



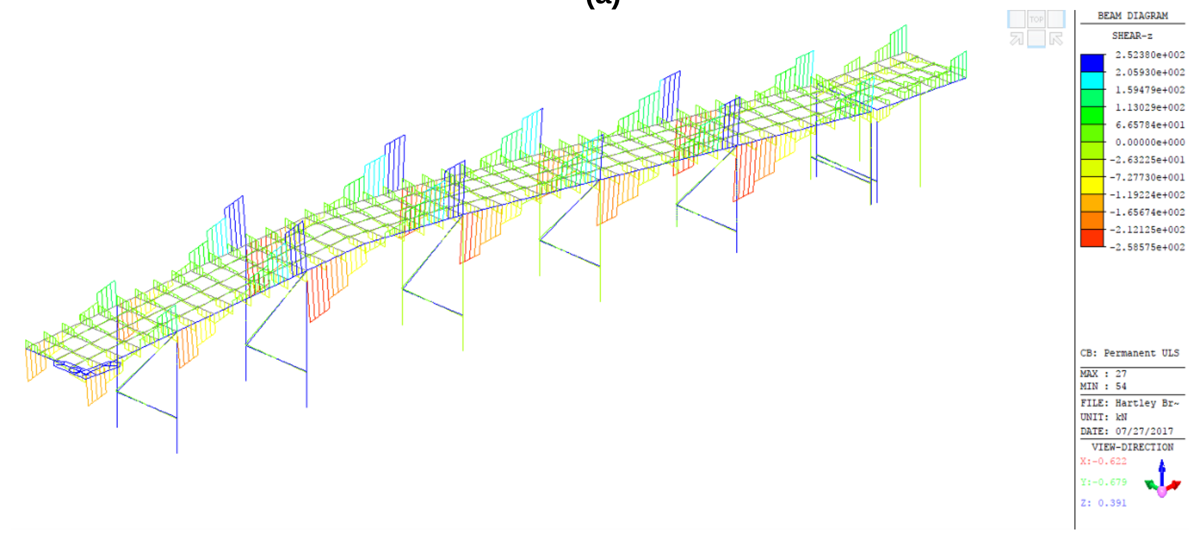
(b)

Figure B.1 Hartley Bridge Grillage Computer Model: (a) isometric rendered view of the bridge, (b) isometric view of the bridge mesh elements

B.1.1 LOAD EFFECTS for Parapet Beam Assessment – Permanent Load



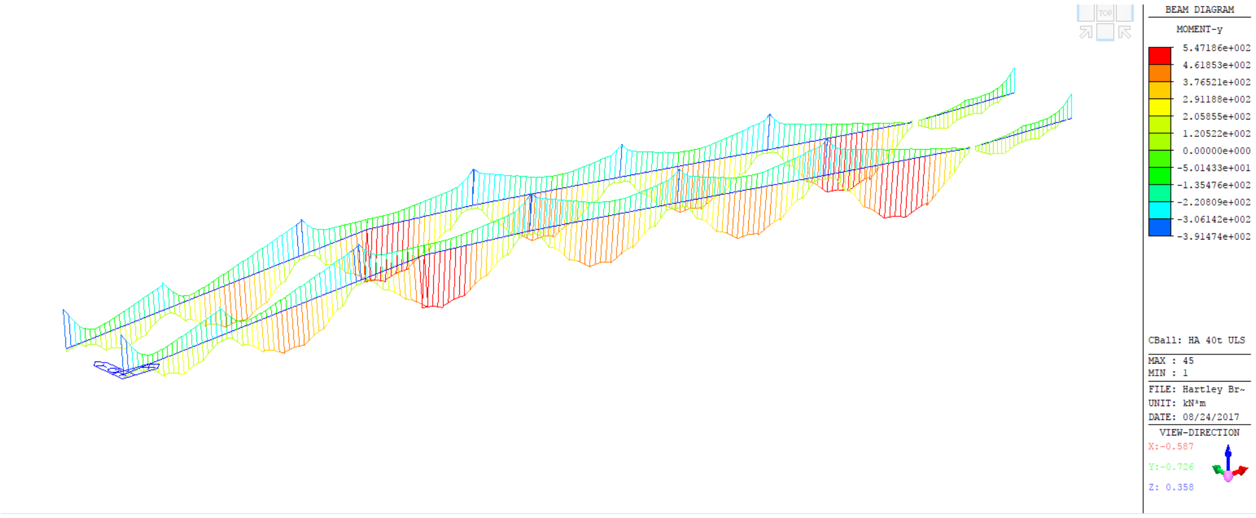
(a)



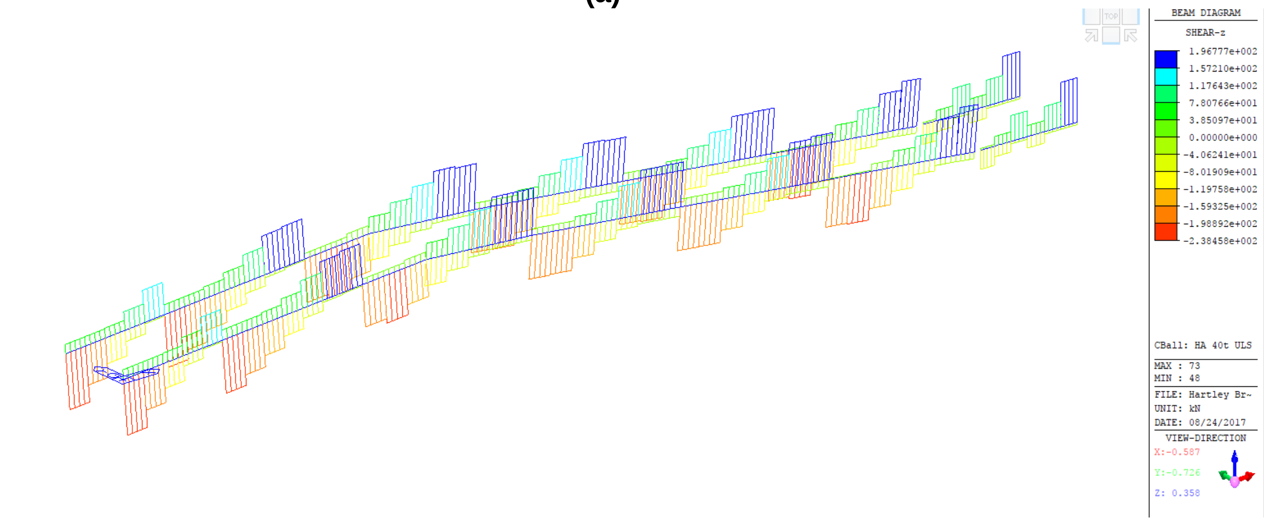
(b)

Figure B.1.1 Diagrams of Maximum and Minimum "Permanent" ULS Load Effect Distributions: (a) – Bending moment (kNm), (b) – Shear force (kN).

B.1.2 LOAD EFFECTS for Parapet Beam Assessment – Perm+40t HA LL



(a)



(b)

Figure B.1.2 Diagrams of Maximum and Minimum "Permanent & 40t HA LL" ULS Load Effect Distributions: (a) – Bending moment (kNm), (b) – Shear force (kN).

B.1.3 LOAD EFFECTS for Deck Slab Assessment

ROD ROUGHAN & O'DONOVAN	Member/Location		Sheet no: 1
	Deck Slab Loading	Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref. | *Calculations* | *Remarks*

Deck Slab Loading Calculation

Material Densities

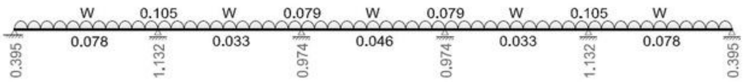
γconc	24	kN/m³	Concrete
γsurfacing	25.6	kN/m³	Surfacing
γfill	20.0	kN/m³	General fill

Geometry

D	0.140	m	Depth of slab
A_{slab}	0.140	m²/m	Sectional area of slab
D_{surf}	0.070	m	Depth of Surfacing
D_{fill}	0.230	m	Depth of general fill
L	1.540	m	Typical slab span

Permanent Loading

			γfl	γf3	Factored load	
Self weight	3.36	kN/m	1.15	1.10	4.25	kN/m/m
Surfacing	1.79	kN/m	1.75	1.10	3.45	kN/m/m
General fill	4.60	kN/m	1.20	1.10	6.07	kN/m/m
Total					13.77	kN/m/m



W 21.21 kN/m

Maximum moments

<u>Hogging BM</u>

coefficient 0.105 from diagram
BM 3.429 kNm

<u>Sagging BM</u>

coefficient 0.078 from diagram
BM 2.548 kNm

Maximum Reaction

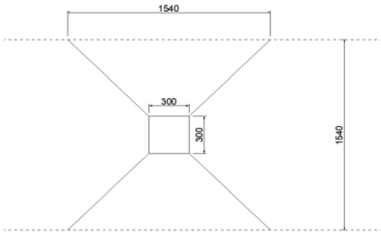
coefficient 1.132 from diagram
R 24.01 kN

Live Loading

BD21/14 Cl. 5.33

Single wheel loading

Wheel load distribution:



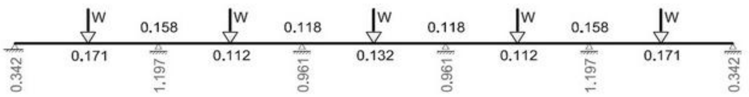
ROD ROUGHAN & O'DONOVAN	Member/Location **Deck Slab**			Sheet no: 2
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref.	Calculations	Remarks

5.22 Traffic flow: low

5.23 Road surface: Good

Load distribution 1.54 m



γ_{fl} = 1.5

γ_{f3} = 1.1

Load effects - mid-span

BM coefficient 0.171 from diagram

Shear coefficient 1.197 from diagram

Assessment loading	Lg (kN)	Applied Moment	Applied Shear (kN)	Total bending moment (kNm)	Total shear force (kN)
40 tonne	82	35.6	105.2	38.2	129.2
26 tonnes	82	35.6	105.2	38.2	129.2
18 tonnes	82	35.6	105.2	38.2	129.2
7.5 tonnes	41	17.8	52.6	20.4	76.6
3 tonnes	19	8.3	24.4	10.8	48.4
FE group 1	50	21.7	64.1	24.3	88.1
FE Group 2	25	10.9	32.1	13.4	56.1

Load effects - supports

BM coefficient 0.158 from diagram

Shear coefficient 1.197 from diagram

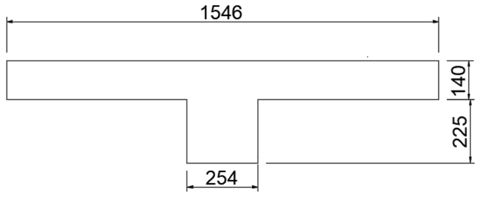
Assessment loading	Lg (kN)	Applied Moment	Applied Shear (kN)	Total bending moment (kNm)	Total shear force (kN)
40 tonne	82	32.9	105.2	35.5	129.2
26 tonnes	82	32.9	105.2	35.5	129.2
18 tonnes	82	32.9	105.2	35.5	129.2
7.5 tonnes	41	16.5	52.6	19.0	76.6
3 tonnes	19	7.6	24.4	10.2	48.4
FE group 1	50	20.1	64.1	22.6	88.1
FE Group 2	25	10.0	32.1	12.6	56.1

B.1.4 LOAD EFFECTS for Transverse Beams Assessment

ROD	Member/Location **Deck Beams - Over piers**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181	Date:	Date:

Ref.	*Calculations*	*Remarks*

Transverse Beam Loading Calculation



Material Densities

γconc	24	kN/m^3	Concrete
γsurfacing	25.6	kN/m^3	Surfacing
γfill	20.0	kN/m^3	General fill

Geometry

A_{beam}	0.27	m^2	Sectional area of beam
D_{surf}	0.070	m	Depth of Surfacing
D_{fill}	0.230	m	Depth of general fill
L	5.190	m	Length of beam

Permanent Loading

		γfl	γf3	Factored load
Self weight	6.57 kN/m	1.15	1.10	8.31 kN/m
Surfacing	2.77 kN/m	1.75	1.10	5.33 kN/m
General fill	5.89 kN/m	1.20	1.10	7.77 kN/m/m
Total				21.41 kN/m

Bending moment 72.09 kNm
Shear 55.56 kN

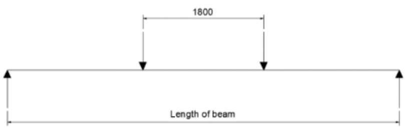
Remarks: assumed as simply support beam

Live Loading

Ref: BD21/14 5.22 5.23

Traffic flow: low
Road surface: Good

Spacing between wheels = 1.8 m



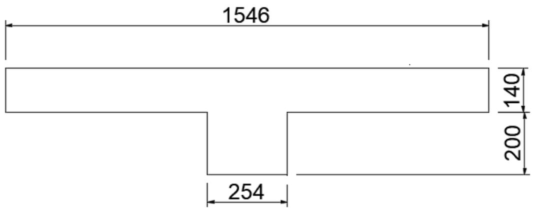
γfl = 1.5
γf3 = 1.1

Assessment loading	Lg (kN)	Applied Moment (kNm)	Applied Shear (kN)	Total bending moment (kNm)	Total shear force (kN)
40 tonne	82	229.3	135.3	301.4	190.9
26 tonnes	82	229.3	135.3	301.4	190.9
18 tonnes	82	229.3	135.3	301.4	190.9
7.5 tonnes	41	114.7	67.7	186.8	123.2
3 tonnes	19	53.1	31.4	125.2	86.9
FE group 1	50	139.8	82.5	211.9	138.1
FE Group 2	25	69.9	41.3	142.0	96.8

ROD Roughan & O'Donovan	Member/Location **Deck Beams - Mid span**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181	Date:	Date:

Ref. | *Calculations* | *Remarks*

Transverse Beam Loading Calculation



Material Densities

γconc	24	kN/m^3	Concrete
γsurfacing	25.6	kN/m^3	Surfacing
γfill	20.0	kN/m^3	General fill

Geometry

A_{beam}	0.27	m^2	Sectional area of beam
D_{surf}	0.070	m	Depth of Surfacing
D_{fill}	0.230	m	Depth of general fill
L	5.190	m	Length of beam

Permanent Loading

			γfl	γf3	Factored load	
Self weight	6.41	kN/m	1.15	1.10	8.11	kN/m
Surfacing	2.77	kN/m	1.75	1.10	5.33	kN/m
General fill	5.89	kN/m	1.20	1.10	7.77	kN/m/m
Total					21.22	kN/m

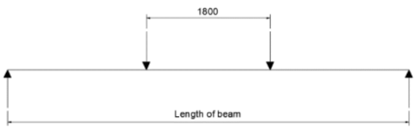
Bending moment 71.44 kNm — *Remarks:* assumed as simply support beam
Shear 55.06 kN

Live Loading

Ref: BD21/14 5.22 5.23

Traffic flow: low
Road surface: Good

Spacing between wheels = 1.8 m



γfl = 1.5
γf3 = 1.1

Assessment loading	Lg (kN)	Applied Moment (kNm)	Applied Shear (kN)	Total bending moment (kNm)	Total shear force (kN)
40 tonne	82	229.3	135.3	300.8	190.4
26 tonnes	82	229.3	135.3	300.8	190.4
18 tonnes	82	229.3	135.3	300.8	190.4
7.5 tonnes	41	114.7	67.7	186.1	122.7
3 tonnes	19	53.1	31.4	124.6	86.4
FE group 1	50	139.8	82.5	211.3	137.6
FE Group 2	25	69.9	41.3	141.4	96.3

B.2. Summary of Assessment Calculations

ROD ROUGHAN & O'DONOVAN		Member/Location **Assessment Summary**		Sheet no:
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref.	*Calculations*	*Remarks*

Deck slab

Mid-span

Condition factor, F_{cm} **0.9**

Bending capacity 23.62 kNm
Shear capacity 93.03 kN (without shear reinforcement)

Assessment loading	Total applied moment (kNm)	AR	Total applied shear (kN)	AR	Pass/Fail
40 tonne	38.18	1.62	129	1.39	FAIL
26 tonnes	38.18	1.62	129	1.39	FAIL
18 tonnes	38.18	1.62	129	1.39	FAIL
7.5 tonnes	20.36	0.86	77	0.82	PASS
3 tonnes	10.80	0.46	48	0.52	PASS
FE group 1	24.27	1.03	88	0.95	FAIL
FE Group 2	13.41	0.57	56	0.60	PASS

Supports

Condition factor **0.9**

Bending capacity 12.21 kNm
Shear capacity 93.03 kN (without shear reinforcement)

Assessment loading	Total applied moment (kNm)	AR	Total applied shear (kN)	AR	Pass/Fail
40 tonne	35.47	2.90	129	1.39	FAIL
26 tonnes	35.47	2.90	129	1.39	FAIL
18 tonnes	35.47	2.90	129	1.39	FAIL
7.5 tonnes	19.01	1.56	77	0.82	FAIL
3 tonnes	10.18	0.83	48	0.52	PASS
FE group 1	22.62	1.85	88	0.95	FAIL
FE Group 2	12.58	1.03	56	0.60	FAIL

	Member/Location		Sheet no:
	Assessment Summary	Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref. | *Calculations* | *Remarks*

Deck Beams - Over pier

Mid-span

Condition factor, F_{cm} 0.9

Bending capacity 195.06 kNm
Shear capacity 270.27 kN

Assessment loading	Total applied moment (kNm)	AR	Total applied shear (kN)	AR	Pass/Fail
40 tonne	301.43	1.55	191	0.81	FAIL
26 tonnes	301.43	1.55	191	0.81	FAIL
18 tonnes	301.43	1.55	191	0.81	FAIL
7.5 tonnes	186.76	0.96	123	0.52	PASS
3 tonnes	125.23	0.64	87	0.37	PASS
FE group 1	211.93	1.09	138	0.59	FAIL
FE Group 2	142.01	0.73	97	0.41	PASS

Deck Beams - Mid span

Mid-span

Condition factor, F_{cm} 0.9

Bending capacity 156.16 kNm
Shear capacity 235.78 kN

Assessment loading	Total applied moment (kNm)	AR	Total applied shear (kN)	AR	Pass/Fail
40 tonne	300.78	1.93	190	0.81	FAIL
26 tonnes	300.78	1.93	190	0.81	FAIL
18 tonnes	300.78	1.93	190	0.81	FAIL
7.5 tonnes	186.11	1.19	123	0.52	FAIL
3 tonnes	124.58	0.80	86	0.37	PASS
FE group 1	211.28	1.35	138	0.58	FAIL
FE Group 2	141.36	0.91	96	0.41	PASS

	Member/Location		Sheet no:
ROD ROUGHAN & O'DONOVAN	**Assessment Summary**	Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref. | *Calculations* | *Remarks*

Parapet Beams (Mid span)

Tension side

Condition factor, F_{cm} 0.9

Bending capacity 939 kNm
Shear capacity 405 kN With shear reinforcement

ULS Permanent Load effects (from MIDAS model)

Bending moment 412 kNm
Shear force 280 kN

ULS Live Loading (from MIDAS Model)

Assessment loading	Total applied moment (kNm)	Total applied shear (kN)
40 tonne	544.00	194.00
26 tonnes	539.00	192.00
18 tonnes	395.20	141.00
7.5 tonnes	221.50	79.00
3 tonnes	143.30	51.10
FE group 1	358.20	127.90
FE Group 2	178.00	63.50

Total load effects

Assessment loading	Total applied moment (kNm)	AR	Total applied shear (kN)	AR	Pass/Fail
40 tonne	956.00	1.02	474	1.17	FAIL
26 tonnes	951.00	1.01	472	1.16	FAIL
18 tonnes	807.20	0.86	421	1.04	FAIL
7.5 tonnes	633.50	0.67	359	0.89	PASS
3 tonnes	555.30	0.59	331	0.82	PASS
FE group 1	770.20	0.82	408	1.01	FAIL
FE Group 2	590.00	0.63	344	0.85	PASS

Member/Location	Sheet no:
Assessment Summary	
Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181
Date:	Date:

Ref. *Calculations* *Remarks*

Parapet Beams (At supports)

Compression Side

Condition factor, F_{cm} 0.9

Bending capacity 622.4 kNm
Shear capacity 407.3 kN with shear reinforcement

ULS Permanent Load effects (from MIDAS Model)

Bending moment 499.2 kNm
Shear force 269.4 kN

ULS Live Loading (from MIDAS Model)

Assessment loading	Total applied moment (kNm)	Total applied shear (kN)
40 tonne	357.30	194.00
26 tonnes	333.00	192.00
18 tonnes	259.30	141.00
7.5 tonnes	145.30	79.00
3 tonnes	94.00	51.10
FE group 1	235.10	127.90
FE Group 2	116.80	63.50

Total load effects

Assessment loading	Total applied moment (kNm)	AR	Total applied shear (kN)	AR	Pass/Fail
40 tonne	856.50	1.38	463	1.14	FAIL
26 tonnes	832.20	1.34	461	1.13	FAIL
18 tonnes	758.50	1.22	410	1.01	FAIL
7.5 tonnes	644.50	1.04	348	0.86	FAIL
3 tonnes	593.20	0.95	321	0.79	PASS
FE group 1	734.30	1.18	397	0.98	FAIL
FE Group 2	616.00	0.99	333	0.82	PASS

ROD ROUGHAN & O'DONOVAN	Member/Location **Assessment Summary**			Sheet no:
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref. *Calculations* *Remarks*

Columns

Condition factor, F_{cm} 0.9

Ultimate Axial capacity 1719 kN
Ultimate moment capacity 193 kNm

ULS Permanent Load effects (from MIDAS Model)

Max axial with co-existant bending
Axial Force 701 kN
Bending moment 0 kNm

Max bending with co-existant axial
Axial Force 564 kN
Bending moment 86 kNm

ULS Live Loading (from MIDAS Model)

	Max axial with co-existant bending		Max bending with co-existant axial	
Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	Total applied axial (kN)	Total applied bending (kNm)
40 tonne	398.88	16.69	384.70	70.39
26 tonnes	394.43	16.50	380.42	69.60
18 tonnes	289.46	12.11	279.18	51.08
7.5 tonnes	162.23	6.79	156.46	28.63
3 tonnes	104.97	4.39	101.24	18.52
FE group 1	262.42	10.98	253.10	46.31
FE Group 2	130.42	5.46	125.78	23.01

Total load effects max axial with co-existant bending

Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	AR	Pass/Fail
40 tonne	1099.38	17	0.73	PASS
26 tonnes	1094.93	17	0.72	PASS
18 tonnes	989.96	12	0.64	PASS
7.5 tonnes	862.73	7	0.54	PASS
3 tonnes	805.47	4	0.49	PASS
FE group 1	962.92	11	0.62	PASS
FE Group 2	830.92	5	0.51	PASS

Total load effects max bending with co-existant axial

Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	AR	Pass/Fail
40 tonne	1085.20	70	1.00	PASS
26 tonnes	1080.92	70	0.99	PASS
18 tonnes	979.68	51	0.83	PASS
7.5 tonnes	856.96	29	0.65	PASS
3 tonnes	801.74	19	0.56	PASS
FE group 1	953.60	46	0.80	PASS
FE Group 2	826.28	23	0.60	PASS

	Member/Location		Sheet no:
ROD	**Assessment Summary**	Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref. *Calculations* *Remarks*

Diagonal Brace

Condition factor 0.9

Ultimate Axial capacity 710 kN
Ultimate moment capacity 53 kNm

ULS Permanent Load effects (from MIDAS Model)

Max axial with co-existant bending
Axial Force 45 kN
Bending moment 15 kNm

ULS Live Loading (from MIDAS Model)

	Max axial with co-existant bending		Max bending with co-existant axial	
Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	Total applied axial (kN)	Total applied bending (kNm)
40 tonne	23.71	1.35	3.24	8.85
26 tonnes	21.53	1.23	2.94	8.04
18 tonnes	16.85	0.96	2.30	6.29
7.5 tonnes	10.92	0.62	1.49	4.08
3 tonnes	10.92	0.62	1.49	4.08
FE group 1	15.62	1.15	1.65	4.54
FE Group 2	11.54	0.85	1.54	4.21

Total load effects max axial with co-existant bending

Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	AR	Pass/Fail
40 tonne	68.21	16	0.40	PASS
26 tonnes	66.03	16	0.40	PASS
18 tonnes	61.35	16	0.39	PASS
7.5 tonnes	55.42	16	0.37	PASS
3 tonnes	55.42	16	0.37	PASS
FE group 1	60.12	16	0.39	PASS
FE Group 2	56.04	16	0.38	PASS

Total load effects max bending with co-existant axial

Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	AR	Pass/Fail
40 tonne	47.74	24	0.52	PASS
26 tonnes	47.44	23	0.50	PASS
18 tonnes	46.80	21	0.47	PASS
7.5 tonnes	45.99	19	0.42	PASS
3 tonnes	45.99	19	0.42	PASS
FE group 1	46.15	20	0.43	PASS
FE Group 2	46.04	19	0.43	PASS

ROD Roughan & O'Donovan	Member/Location **Assessment Summary**			Sheet no:
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref. | *Calculations* | *Remarks*

Horizontal Tie

Condition factor 0.9

Ultimate Axial capacity 605 kN
Ultimate moment capacity 37 kNm

ULS Permanent Load effects (from MIDAS Model)

Max axial with co-existant bending
Axial Force 51 kN
Bending moment 6 kNm

ULS Live Loading (from MIDAS Model)

	Max axial with co-existant bending	
Assessment loading	Total applied axial (kN)	Total applied bending (kNm)
40 tonne	43.58	0.00
26 tonnes	39.57	0.00
18 tonnes	30.97	0.00
7.5 tonnes	20.07	0.00
3 tonnes	20.07	0.00
FE group 1	24.65	0.00
FE Group 2	21.00	0.00

Total load effects max axial with co-existant bending

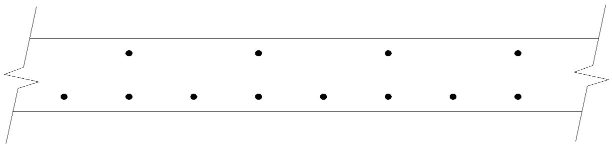
Assessment loading	Total applied axial (kN)	Total applied bending (kNm)	AR	Pass/Fail
40 tonne	94.58	6	0.30	PASS
26 tonnes	90.57	6	0.23	PASS
18 tonnes	81.97	6	0.22	PASS
7.5 tonnes	71.07	6	0.20	PASS
3 tonnes	71.07	6	0.20	PASS
FE group 1	75.65	6	0.21	PASS
FE Group 2	72.00	6	0.21	PASS

B.3. Structural Capacity Calculations

ROUGHAN & O'DONOVAN	Member/Location **Deck slab - Structural Capacity**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181	Date:	Date:

Ref.	*Calculations*	*Remarks*

Reinforced Concrete Bending Resistance Calculation to BD44/95



Material Properties

Ref.					
BD44-95	fy	250	N/mm^2	steel strength
CL. 5.3.2	fcu	36	N/mm^2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm^2	

Section Geometry

b	1.000	m	breadth of section
h	0.140	m	depth of section
x	57	mm	depth of neutral axis

tension cover	20	mm	(based on cover survey)
compression cover	20	mm	

	Tension Reinforcement		Spacing		No.	dis from centroid to face of concrete
Layer 1	Φ	0 mm		No.		mm
Layer 2	Φ	0 mm		No.		mm
Layer 3	Φ	12 mm	110 mm	No.	9	26 mm

	Compression Reinforcement		Spacing		No.	dis from centroid to face of concrete
Layer 1	Φ	12 mm	215 mm	No.	5	26 mm
Layer 2	Φ	0 mm		No.	0	mm

Tension bars	Layer	As prov (mm2)	d (depth to centroid)				
	1	0	140				
	2	0	140	d	114	mm	effective depth
	3	1028	114	z	107	mm	lever arm

Comp bars	Layer	As prov (mm2)	d (depth to centroid)				
	1	526	114	d	114	mm	effective depth
	2	0	140	d'	26	mm	depth to compression rebar
				z	108		

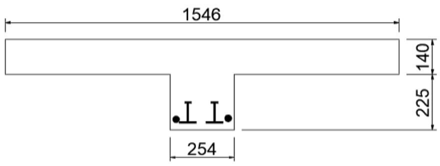
ROD ROUGHAN & O'DONOVAN	Member/Location **Deck slab**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181	Date:	Date:

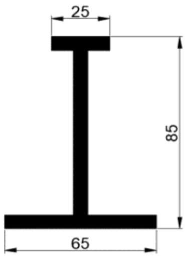
Ref.	*Calculations*	*Remarks*
	Moment Capacity in Sagging	
	Mu **26.24** kNm ultimate moment resistance in sagging	
	With compression rebar	
	x 7 mm	
	0.429x 3 mm **IGNORE COMPRESSION REBAR!**	
	Moment Capacity in Hogging	
	Mu **13.57** kNm ultimate moment resistance in hogging	
	M 35 kNm design moment	
	Util 2.61 not ok *Ignoring Compression Rebar*	
	Reinforced Concrete Shear Resistance calculation to BD44/95	
BD44-95	V 118 KN design shear force	
CL. 5.3.3	v 1.03 N/mm2 shear stress	
	Without shear reinforcement	
	ξs 1.48	
	0.90	
	vc 0.61 N/mm2	
	Vu **103.37** KN	

ROD ROUGHAN & O'DONOVAN		Member/Location **Deck Beams Over piers - Structural Capacity**		Sheet no:
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref. | *Calculations* | *Remarks*

Reinforced Concrete Bending Resistance Calculation to BD44/95





Steel moss bars

Material Properties

Ref.				
BD44-95	fy	250	N/mm^2	steel strength
CL. 5.3.2	fcu	36	N/mm^2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm^2	

Section Geometry

b	1.546	m	breadth of section
h	0.365	m	depth of section
x	139	mm	depth of neutral axis
Mo	1413	mm^2	sectional area of moss bar

tension cover	50	mm
compression cover	N/A	mm

Tension Reinforcement

				Spacing				dis from centroid to face of	
Layer 1	Φ	0	mm			No.			mm
Layer 2	Φ	1413	mm^2	N/A		No.	2	93	mm
Layer 3	Φ	20	mm	N/A	mm	No.	2	60	mm

Compression Reinforcement

				Spacing				dis from centroid to face of	
Layer 1	Φ	0	mm	242	mm	No.	6	N/A	mm
Layer 2	Φ	0	mm			No.	0		mm

Tension bars

Layer	As prov (mm2)	d (depth to centroid)				
1	0	365				
2	2826	273	d	278	mm	effective depth
3	628	305	z	263.52	mm	lever arm

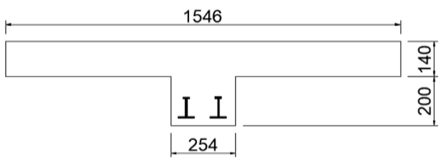
		Member/Location		
		Deck Beams Over piers - Structural Capacity		Sheet no:
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

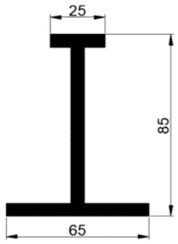
Ref.	Calculations				Remarks
	Moment Capacity in Sagging				
	Mu	**216.73**	kNm	ultimate moment resistance in sagging	
	Reinforced Concrete Shear Resistance calculation to BD44/95				
BD44-95	V	191	KN	design shear force	
CL. 5.3.3	v	0.44	N/mm2	shear stress	
	Without shear reinforcement				
	ξs	1.19			
		0.80			
	vc	0.59	N/mm2		
	Vu	**300.30**	KN	shear capacity	

ROD ROUGHAN & O'DONOVAN	Member/Location **Deck Beams - mid span**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181	Date:	Date:

Ref.	*Calculations*	*Remarks*

Reinforced Concrete Bending Resistance Calculation to BD44/95





Material Properties

Ref.				
BD44-95	fy	250	N/mm^2	steel strength
CL. 5.3.2	fcu	30	N/mm^2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm^2	

Section Geometry

b	1.546	m	breadth of section
h	0.340	m	depth of section
x	136	mm	depth of neutral axis
Mo	1413	mm^2	sectional area of moss bar

tension cover	25	mm
compression cover	N/A	mm

	Tension Reinforcement			Spacing				dis from centroid to face of	
Layer 1	Φ	0	mm			No.			mm
Layer 2	Φ	0	mm			No.			mm
Layer 3	Φ	1413	mm^2	N/A	mm	No.	2	68	mm

	Compression Reinforcement			Spacing				dis from centroid to face of	
Layer 1	Φ	0	mm		mm	No.			mm
Layer 2	Φ	0	mm			No.	0		mm

Tension bars	Layer	As prov (mm2)	d (depth to centroid)				
	1	0	340				
	2	0	340	d	273	mm	effective depth
	3	2826	273	z	257.88	mm	lever arm

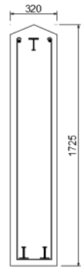
ROD ROUGHAN & O'DONOVAN	Member/Location **Deck Beams - mid span**			Sheet no:
		Calcs by: SH		Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181	Date:		Date:

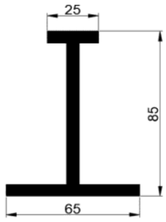
Ref.	*Calculations*				*Remarks*
	Moment Capacity in Sagging				
	Mu	**173.51**	kNm	ultimate moment resistance in sagging	
	Moment Capacity in Hogging			No rebar in top of beam	
	Mu	**N/A**	kNm	ultimate moment resistance in hogging	
	M	**4724**	kNm	design moment	
	Util	-	-	*Ignoring Compression Rebar*	
	Reinforced Concrete Shear Resistance calculation to BD44/95				
BD44-95	V	**191**	KN	design shear force	
CL. 5.3.3	v	0.45	N/mm2	shear stress	
	Without shear reinforcement				
	ξs	1.19			
		0.67			
	vc	0.52	N/mm2		
	Vu	**261.98**	KN	shear capacity	

	Member/Location **Parapet Beam**			Sheet no:
			Calcs by: SH	Checked by:
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref.	Calculations	Remarks

Reinforced Concrete Bending Resistance Calculation to BD44/95





Steel moss bars

Material Properties

Ref.				
BD44-95	fy	250	N/mm2	steel strength
CL. 5.3.2	fcu	36	N/mm2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm2	

Section Geometry

b	0.320	m	breadth of section
h	1.725	m	depth of section
x	816	mm	depth of neutral axis
Mo	1413	mm^2	sectional area of moss bar

tension cover	50	mm
compression cover	50	mm

	Tension Reinforcement			Spacing				dis from centroid to face of		Remarks
Layer 1	Φ		mm	N/A	mm	No.			mm	
Layer 2	Φ		mm	N/A	mm	No.			mm	
Layer 3	Φ		mm	N/A	mm	No.			mm	
Layer 4	Φ	1413.0	mm^2	N/A	mm	No.	2	93	mm	2No. Moss Bars

	Compression Reinforcement			Spacing				dis from centroid to face of		Remarks
Layer 1	Φ	1413.0	mm^2	N/A	mm	No.	1	93	mm	1No. Moss Bars
Layer 2	Φ	16.0	mm	N/A	mm	No.	2	58	mm	2x 16mm bars

Tension bars	Layer	As prov (mm2)	d (depth to centroid)				
	1	0	1725				
	2	0	1725	d	1633	mm	effective depth
	3	0	1725				
	4	2826	1633	z	1551	mm	lever arm

Comp bars	Layer	As prov (mm2)	d (depth to centroid)				
	1	1413	1633	d	1640	mm	effective depth
	2	402	1667	d'	85	mm	depth to compression rebar
				z	1558		

ROD (Roughan & O'Donovan)	Member/Location **Parapet Beam**		Sheet no:
		Calcs by: SH	Checked by:
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref. | *Calculations* | *Remarks*

Moment Capacity in Sagging

Mu	**1043.52**	kNm	ultimate moment resistance in sagging

With compression rebar

x	50	mm
0.429x	21	mm

Mu	**1104.62**	kNm	ultimate moment resistance
M	1010	kNm	design moment
Util	0.91	ok	

Moment Capacity in Hogging

Mu	**673.38**	kNm	ultimate moment resistance in hogging	
M	1000	kNm	design moment	
Util	1.49	not ok		*Ignoring Compression Rebar*

Reinforced Concrete Shear Resistance calculation to BD44/95

Ref.				
BD44-95	V	427	KN	design shear force
CL. 5.3.3	v	0.82	N/mm2	shear stress

Without shear reinforcement

ξs	0.76	
	0.54	
vc	0.52	N/mm2
Vu	**205.39**	KN

With shear reinforcement

	Vertical links		Inclined links `		
α	90	degrees	45	degrees	inclination of shear rebar to axis of member
angle ok					
No of legs	2		2		
thk	4	mm	4	mm	
width	25	mm	25	mm	
Asv	100	mm2	100	mm2	
sv	315	mm	320	mm	spacing of links along member

23810 > 20160   33672 > 20480 **OK**

Additional shear capacity

123 KN   121 KN

z 1469 lever arm

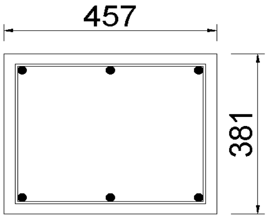
672857 > 798231 **links are not effective**

Vu	**450**	KN	ultimate shear capacity with shear links

ROD ROUGHAN & O'DONOVAN	Member/Location **Pier columns**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref.	*Calculations*	*Remarks*

Reinforced Concrete Column Resistance Calculation to BD44/14



Material Properties

Ref.				
BD44-14	fy	250	N/mm2	steel strength
CL. 5.3.2	fcu	36	N/mm2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm2	

Section Geometry

b	0.457	m	breadth of section
h	0.381	m	depth of section
x	173	mm	depth of neutral axis
Ac	174117	mm2	Area of concrete

cover 25 mm

	Tension Reinforcement			Spacing				dis from centroid to face of	
Layer 1	Φ	19	mm	N/A	mm	No.	3	35	mm
	Compression Reinforcement			Spacing				dis from centroid to face of	
Layer 1	Φ	19	mm	N/A	mm	No.	3	35	mm

	Layer	As prov (mm2)	d (depth to centroid)				
Tension bars				d	347	mm	effective depth
	1	851	347	z	329	mm	lever arm

	Layer	As prov (mm2)	d (depth to centroid)				
Comp bars	1	851	347	d	347	mm	effective depth
				d'	35	mm	depth to compression rebar
				z	329		

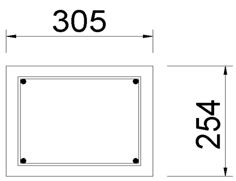
ROD ROUGHAN & O'DONOVAN	Member/Location **Pier columns**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref.	*Calculations*				*Remarks*
5.5.3.4	**Axial compression resistance**				
	d_c	228.5	mm	depth of concrete in compression	
	f_{yc}	212.8	N/mm^2	compressive strength of steel	
	A'sl	851	mm2	area of compression reinforcement	
	fs2	190.5	N/mm^2	stress in reinforcement in other face	
	As2	851	mm2	area of reinforcement in other face	
eq. 14	**Nu**	**1910**	**kN**	**Ultimate axial capacity**	
5.5.3.4	**Bending moment capacity**				
	Mu	**214.15**	**kNm**	**Ultimate bending capacity**	

Member/Location	**Diagonal Brace**		Sheet no:
		Calcs by: SH	Checked by:
Job Title: Hartley Bridge	Job No: 16.181	Date:	Date:

Ref.	*Calculations*	*Remarks*

Reinforced Concrete Column Resistance Calculation to BD44/14



Material Properties

Ref.				
BD44-14 CL. 5.3.2	fy	250	N/mm2	steel strength
	fcu	36	N/mm2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm2	

Section Geometry

b	0.305	m	breadth of section
h	0.254	m	depth of section
x	112	mm	depth of neutral axis

cover 25 mm

Ref.				Spacing				dis from centroid to face of
	Tension Reinforcement							
Layer 1	Φ	12	mm	N/A	mm	No.	2	31 mm
	Compression Reinforcement							
Layer 1	Φ	12	mm	N/A	mm	No.	2	31 mm

Ref.	Layer	As prov (mm2)	d (depth to centroid)				
Tension bars				d	223	mm	effective depth
	1	226	223	z	212	mm	lever arm

Ref.	Layer	As prov (mm2)	d (depth to centroid)				
Comp bars	1	226	223	d	223	mm	effective depth
				d'	31	mm	depth to compression rebar
				z	212		

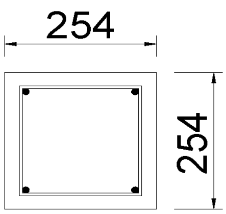
ROD Roughan & O'Donovan	Member/Location **Diagonal Brace**		Sheet no:
		Calcs by: SH	Checked by:
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

Ref.	*Calculations*				*Remarks*
5.5.3.4	**Axial compression resistance**				
	d_c	152.5	mm	depth of concrete in compression	
	f_{yc}	212.8	N/mm^2	compressive strength of steel	
	A'sl	226	mm2	area of compression reinforcement	
	fs2	190.5	N/mm^2	stress in reinforcement in other face	
	As2	226	mm2	area of reinforcement in other face	
eq. 14	**Nu**	**788.4**	**kN**	**Ultimate axial capacity**	
5.5.3.4	**Bending moment capacity**				
	Mu	**59.01**	**kNm**	**Ultimate bending capacity**	

ROD ROUGHAN & O'DONOVAN		Member/Location **Horizontal Tie**		Sheet no:
			Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge	Job No: 16.181		Date:	Date:

Ref.	*Calculations*	*Remarks*

Reinforced Concrete Column Resistance Calculation to BD44/14



Material Properties

Ref.				
BD44-14	fy	250	N/mm2	steel strength
CL. 5.3.2	fcu	36	N/mm2	concrete strength
	γms	1.05		steel material factor
	γmc	1.20		concrete material factor
	γmv	1.25		partial safety factor for shear
	f's	213	N/mm2	

Section Geometry

b	0.254	m	breadth of section
h	0.254	m	depth of section
x	112	mm	depth of neutral axis

cover 25 mm

Tension Reinforcement — Spacing — dis from centroid to face of

Layer 1	Φ	12	mm	N/A	mm	No.	2	31	mm

Compression Reinforcement — Spacing — dis from centroid to face of

Layer 1	Φ	12	mm	N/A	mm	No.	2	31	mm

Tension bars

Layer	As prov (mm2)	d (depth to centroid)				
			d	223	mm	effective depth
1	226	223	z	212	mm	lever arm

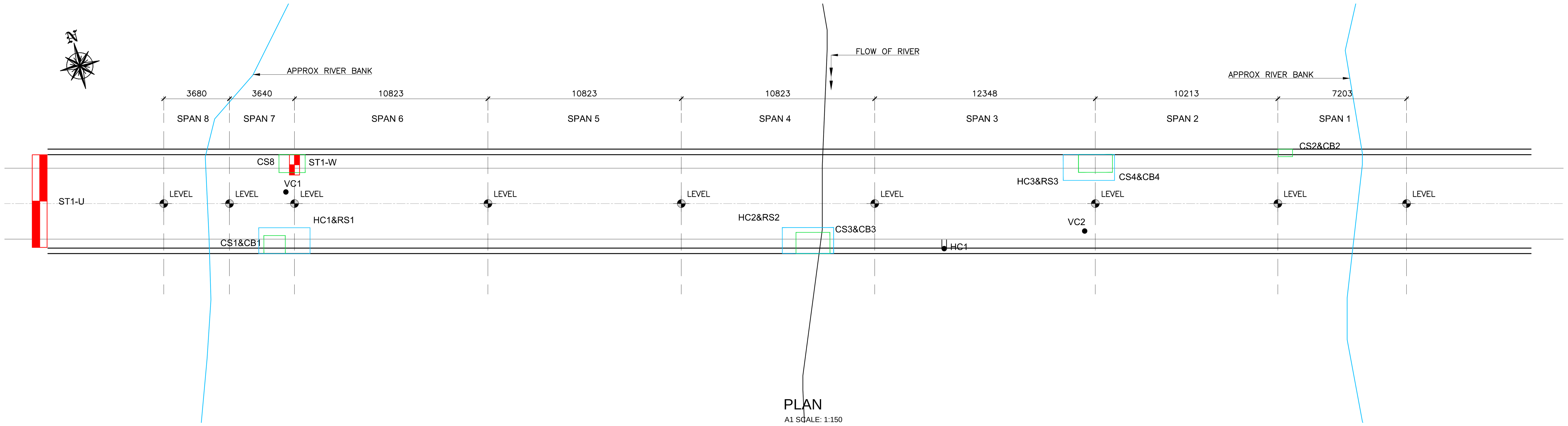
Comp bars

Layer	As prov (mm2)	d (depth to centroid)				
1	226	223	d	223	mm	effective depth
			d'	31	mm	depth to compression rebar
			z	212		

ROUGHAN & O'DONOVAN	Member/Location **Horizontal Tie**		Sheet no:
		Calcs by: SH	Checked by: PK
Job Title: Hartley Bridge / Job No: 16.181		Date:	Date:

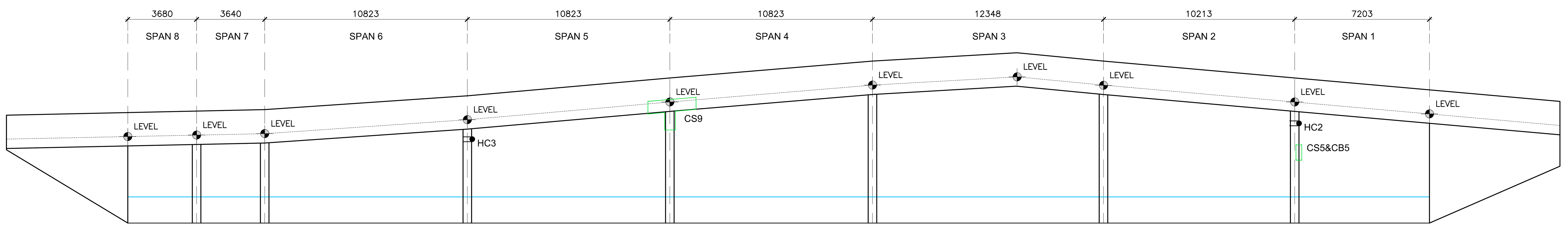
Ref.	*Calculations*				*Remarks*
5.5.3.4	**Axial compression resistance**				
	d_c	127.0	mm	depth of concrete in compression	
	f_{yc}	212.8	N/mm^2	compressive strength of steel	
	A'sl	226	mm2	area of compression reinforcement	
	fs2	190.5	N/mm^2	stress in reinforcement in other face	
	As2	226	mm2	area of reinforcement in other face	
eq. 14	**Nu**	**671.9**	**kN**	**Ultimate axial capacity**	
5.5.3.4	**Bending moment capacity**				
	Mu	**41.49**	**kNm**	**Ultimate bending capacity**	

Appendix C
General Arrangement Drawing



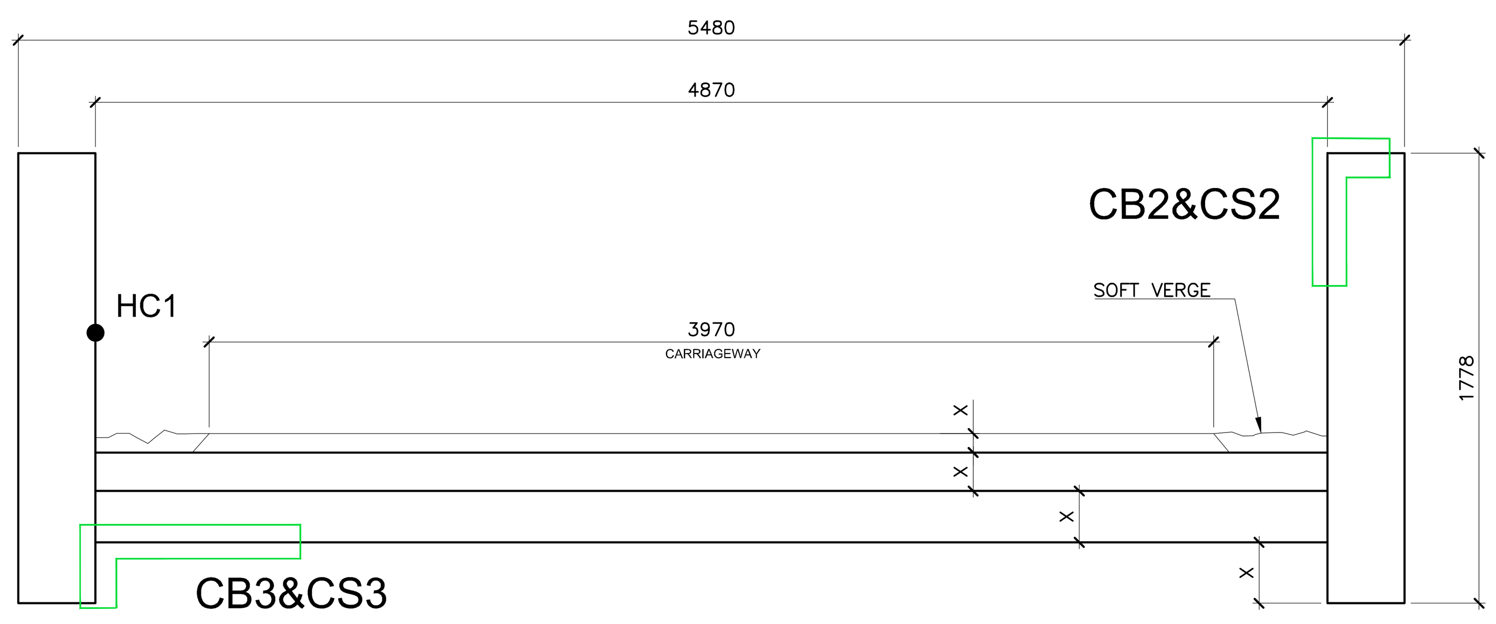
PLAN
A1 SCALE: 1:150
A3 SCALE: 1:300

NOTE: A 2.5m HEIGHT RESTRICTION CURRENTLY EXISTS ON THE BRIDGE

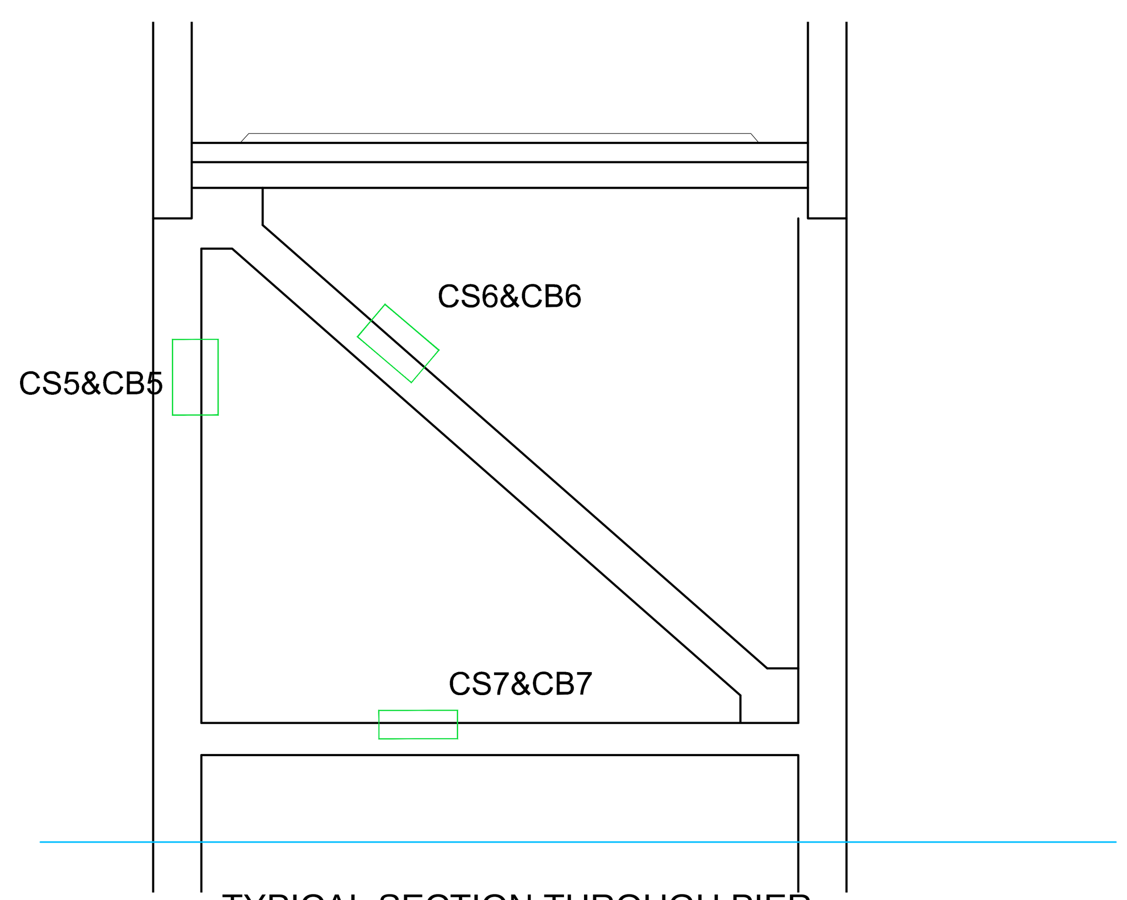


ELEVATION
A1 SCALE: 1:150
A3 SCALE: 1:300

X' DIMS TO BE CONFIRMED IN ALL SPANS



TYPICAL SECTION THROUGH DECK
A1 SCALE: 1:25
A3 SCALE: 1:50



TYPICAL SECTION THROUGH PIER
A1 SCALE: 1:50
A3 SCALE: 1:100

NOTES:

1. STRUCTURAL INVESTIGATION CONTRACTOR TO PROVIDE FULL DIMENSIONAL SURVEY INCLUDING DETAILED CROSS SECTIONS OF THE DECK AND OF INDIVIDUAL MEMBERS AND SPAN LENGTHS. ALL DIMENSIONS SHOWN ON DRAWINGS ARE TO BE CONFIRMED.
2. STRUCTURAL INVESTIGATION CONTRACTOR TO CARRY OUT HAMMER TAP SURVEY TO ESTABLISH EXTENT OF CONCRETE SPALLING.
3. CONTRACTOR TO PROVIDE LEVELS TO ORDNANCE DATUM MALIN HEAD AT LOCATIONS IDENTIFIED WITH ⊕ LEVEL
4. STEEL THICKNESS SHALL BE DETERMINED USING ULTRASONIC THICKNESS GAUGE, DELAMINATED OR CORRODED STEEL TO BE GROUND FLUSH AND PREPARED USING A WIRE BRUSH.
5. IF WATERPROOFING SYSTEM IS PROVIDED IT SHALL BE REINSTATED WITH A COMPATIBLE WATERPROOFING SYSTEM.
6. RIVER SHANNON IS DESIGNATED ENVIRONMENTAL AREA (SAC) CONTRACTOR TO PROVIDE METHOD STATEMENT FOR APPROVAL OF NPWS.

LEGEND:

- ST1 – SILT TRENCH DECK LEVEL
- HC1 – HORIZONTAL CORE
- VC1 – VERTICAL CORE
- CB1 – COVER SURVEY AND CONCRETE BREAKOUT
- – HALF–CELL POTENTIAL AND RESISTIVTY SURVEY

NOTES:

ST1–U	INSPECTION OF UTILITIES
ST1–W	INSPECTION OF BRIDGE SLAB, WATERPROOFING LAYER AND EXPANSION JOINT
CB1&CS1	CONCRETE BREAKOUT AND FERRO SCAN TO DECK SOFFIT TO DETERMINE PARAPET BEAM, TRANSVERSE BEAM AND DECK SLAB REINFORCEMENT DETAILS
CB2&CS2	CONCRETE BREAKOUT AND FERRO SCAN SURVEY TO DETERMINE TOP FLANGE OF PARAPET BEAM REINFORCEMENT DETAILS OVER PIER
CB3&CS3	CONCRETE BREAKOUT AND FERRO SCAN SURVEY TO DECK SOFFIT TO DETERMINE PARAPET BEAM, TRANSVERSE BEAM AND DECK SLAB REINFORCEMENT DETAILS
CB4&CS4	CONCRETE BREAKOUT AND FERRO SCAN SURVEY TO DETERMINE DECK CONTINUITY AND DECK SLAB REINFORCEMENT DETAILS OVER PIER
CB5&CS5	CONCRETE BREAKOUT AND FERRO SCAN SURVEY TO PIER COLUMN TO DETERMINE COLUMN REINFORCEMENT DETAILS
CB6&CS6	CONCRETE BREAKOUT AND FERRO SCAN SURVEY TO PIER DIAGONAL BRACE TO DETERMINE DIAGONAL BRACE REINFORCEMENT DETAILS
CB7&CS7	CONCRETE BREAKOUT AND FERRO SCAN SURVEY TO PIER HORIZONTAL TIE TO DETERMINE HORIZONTAL TIE REINFORCEMENT DETAILS
CS8	FERRO SCAN TO DECK SLAB TO DETERMINE REINFORCEMENT DETAILS
CS9	FERRO SCAN TO TOP OF PIER TO DETERMINE REINFORCEMENT INTERACTION BETWEEN COLUMN, BEAMS AND DECK.
HC1	100mm CORE TO DETERMINE CONCRETE STRENGTH
HC2	100mm CORE TO DETERMINE CONCRETE STRENGTH
HC3	100mm CORE TO DETERMINE CONCRETE STRENGTH
VC1	100mm VERTICAL CORE TO ESTABLISH CONCRETE STRENGTH
VC2	VERTICAL CORE TO ESTABLISH SLAB THICKNESS AND CONCRETE STRENGTH
HC1&RS1	HALF–CELL POTENTIAL AND RESISTIVTY SURVEY TO DETERMINE EXTENT OF CORROSION IN DECK SLAB, TRANSVERSE BEAM AND PARAPET BEAM
HC2&RS2	HALF–CELL POTENTIAL AND RESISTIVTY SURVEY TO DETERMINE EXTENT OF CORROSION IN DECK SLAB, TRANSVERSE BEAM AND PARAPET BEAM
HC3&RS3	HALF–CELL POTENTIAL AND RESISTIVTY SURVEY TO DETERMINE EXTENT OF CORROSION IN DECK SLAB

No.	Revision	Date	By	Chk'd	App'd

Stage	Date	App'd
PRELIMINARY		
APPROVAL		
TENDER		
CONSTRUCTION		

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Project Title: Hartley Bridge - Detailed Structural Investigation Contract

Drawing Title: Structural Invesitgation

Designed: SH	Checked: DC	Approved: JK	Status: PRELIMINARY	
Drawn: SH	Job No: 16.181	Drawing No: 16181-SI-001	Rev: -	
Scale: (A1) AS SHOWN	Date: SEPTEMBER 2016			

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DO NOT SCALE USE FIGURED DIMENSIONS ONLY

Appendix D
Structural Investigation Report

Hartley Bridge
Carrick-on-Shannon
Co. Leitrim
Ireland

Detailed Structural Investigation

2017

Document Issue Register

Distribution	Report Status	Revision	Date of Issue	Prepared by	Approved by
Roughan O'Donovan / Leitrim Co Co	Final	A	23rd July 2017	James Purcell	James Purcell

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Carbonation Test Reports	**Appendix B**
Chloride Ion Test Reports	**Appendix C**
Steel Tensile Test Report	**Appendix D**
Steel Reinforcement Surveys & Trial Pit/Trenches	**Appendix E**
Half Cell Potential & Resistivity Reports	**Appendix F**

1.0 Project Overview

The project involved the gathering, manipulation and compilation of structural investigation data to facilitate the assessment of Hartley Bridge.

The structure spans over the River Shannon on the Co Leitrim / Co Roscommon border and located in the town land of Hartley on the LP3400 approximately 2km north of Carrick on Shannon. There is currently a 2.5m height restriction posted on the bridge.

The Investigation provided for trial pits, slit trenches, vertical cores, horizontal cores, concrete breakouts in-situ testing, laboratory testing and preparation of a Factual Report in accordance with the Specification developed by Roughan O'Donovan Consulting Engineers.

The Investigation is intended to provide information for the Employer in respect of the structural condition of the bridge and will be used to assess the existing condition to enable evaluation of the proposed strengthening/replacement works.

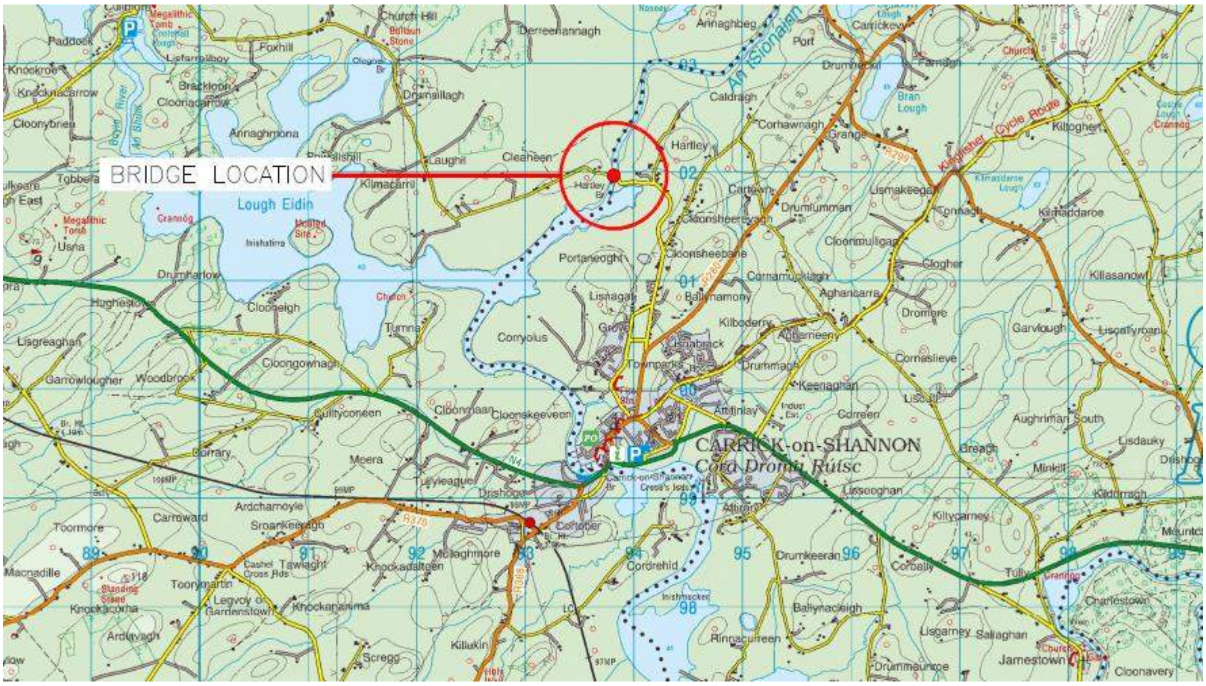
BHP was contracted by Leitrim County Council to provide the series of insitu sampling and excavating, measuring and testing services as well as associated laboratory testing.

2.0 Project Requirements

As directed by the project specification the requirements of the works included:

- Slit Trenches and trial pits identifying structures and utilities.
- Vertical and horizontal coring through concrete slabs and beams.
- Concrete breakouts to confirm reinforcement bar sizes
- Half-cell potential and resistivity surveys to determine extent of corrosion in rebar
- Dimensional and Reinforcement Scan surveys.
- Laboratory testing of steel, concrete and concrete dust samples
- Preparation of detailed Main Factual Report.
- Liaison with the Leitrim County Council and external bodies.

3.0 Location of Works



4.0 Summary of Results

4.1 Concrete Strength Testing

In line with the project specification, BHP removed a number of cores from the concrete bridge deck, side wall and piers that were accessible from the underbridge unit in the centre of the bridge and from the west bank of the bridge. These were cored using a water cooled diamond drill. The cores were individually marked and placed in sealed plastic bags for transportation to the laboratory.

The concrete cores were visually assessed by BHP's technical manager Seamus O'Connell. They were then prepared and tested for density and strength.

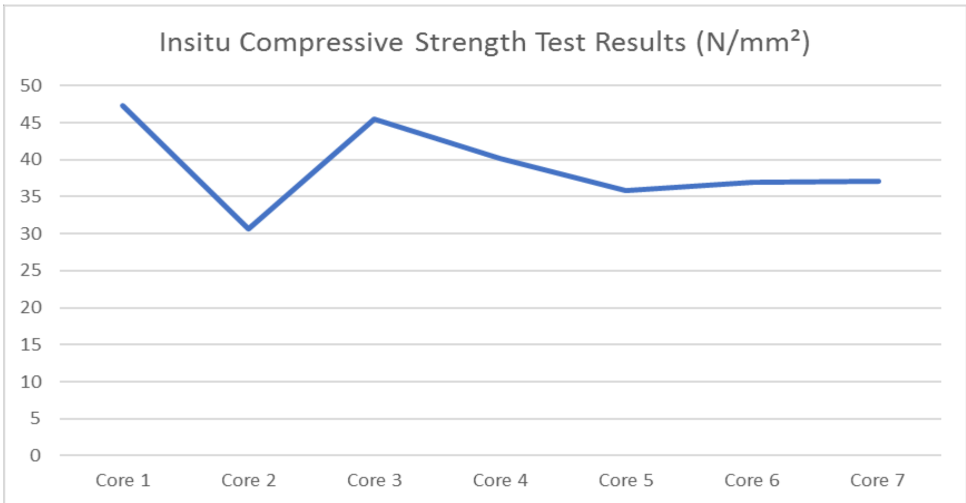
A summary of the results is contained below with full reports contained in Appendix A of this report.

Core	Description	Density	Strength
Core 1	20mm Gravel Mix with 2% voids	2360kg/m³	47.3N/mm²
Core 2	20mm Gravel Mix with 2% voids	2150kg/m³	30.7N/mm²
Core 3	20mm Gravel Mix with 2% voids	2370kg/m³	45.5N/mm²
Core 4	20mm Gravel Mix with 2% voids	2430kg/m³	40.1N/mm²
Core 5	20mm Gravel Mix with 3% voids	2350kg/m³	35.8N/mm²
Core 6	20mm Gravel Mix with 3% voids	2410kg/m³	36.9N/mm²
Core 7	20mm Gravel Mix with 2% voids	2420kg/m³	37.1N/mm²

Core 1 and 3 come from the main concrete deck slab of the bridge. Both cores seem to indicate good quality concrete with a mean concrete core strength result of 46.4N/mm² with and a mean density of 2370kg/m³.

Core 2 comes from the screed that was placed directly on top of the bridge deck slab at location VC 1. The core had a strength of 30.7N/mm² with and a density of 2150kg/m³.

Cores 4 - 7 were horizontal cores that came from either the bridge wing wall (Core 4) or the RC piers at two locations (Core 4 – 7). The pier cores seem to indicate a reasonably high voids of 5% with the visual description of the cores identifying "poor compaction". The horizontal concrete cores had a mean concrete core strength result of 37.5N/mm² with and a mean density of 2400kg/m³.



4.2 Carbonation Testing

In accordance with the project specification, the carbonation testing was performed at eight locations on the underside of Hartley Bridge. The location of these were selected by BHP and noted on the site drawings that accompany this report (Appendix B – Carbonation). The tests were performed on lump samples obtained from the different structural elements. The method employed was to saw cut a 3” deep hole through the given area. A sharpened chisel was then used to break one of the sides of the saw cut. This produced a lump sample. There are two sides to this lump – the saw cut side and the rough freshly broken face. The test is performed on the freshly broken side.

Carbonation testing is carried out to determine the depth of concrete affected due to a combined attack of atmospheric carbon dioxide and moisture causing a reduction in the level of alkalinity in concrete. Cement paste has a pH of approximately 13 which provides a protective layer (passive coating) to the steel reinforcement against corrosion. Loss of passivity occurs at about pH 9.

A 2% phenolphthalein indicator is used for the test. This is applied to freshly exposed concrete surface as detailed above.

Once the indicator is applied to the concrete surface, the change of colour of concrete to pink indicates that the concrete is in good health/condition. Where no change in colour takes place, it is suggestive of carbonation-affected concrete.

The results of the tests performed at Hartley Bridge are contained in Appendix B of this report.

A summary of the results is contained below:

Core	**Ref**	**Carbonation Depth**
Sample 1	Inside face of diagonal support beam for column	2mm
Sample 2	East face of column at highest half-cell reading	3mm
Sample 3	Soffit of deck slab at highest half-cell reading	8mm
Sample 4	Soffit of deck slab	7mm
Sample 5	Column (over land)	15mm
Sample 6	Column (over land)	14mm
Sample 7	Soffit of deck slab (over land)	24mm
Sample 8	Soffit of deck slab (over land)	22mm

4.3 Chloride Ion Testing

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination and spalling.

Steel corrodes because it is not a naturally occurring material. Rather, iron ore is smelted and refined to produce steel. The production steps that transform iron ore into steel add energy to the metal. Steel, like most metals except gold and platinum, is thermodynamically unstable under normal atmospheric conditions and will release energy and revert back to its natural state – iron oxide, or rust. This process is called corrosion.

Corrosion is an electrochemical process involving the flow of charges (electrons and ions). At active sites on the reinforcement bar, called anodes, iron atoms lose electrons and move into the surrounding concrete as ferrous ions. This process is called a half-cell oxidation reaction, or anodic reaction.

Corrosion of embedded metals in concrete can be greatly reduced by placing crack-free concrete with low permeability and sufficient concrete cover. Additional measures to mitigate corrosion of steel reinforcement in concrete include the use of corrosion inhibiting admixtures, coating of reinforcement, and the use of sealers and membranes on the concrete surface.

As noted in section *4.2 carbonation*, the breakdown in the protection of reinforcement bars leads to concrete spalling. The depth of carbonation provides a guide as to the risk of corrosion on a particular bar. Concrete that is not carbonated (or has very low levels of carbonation) protects the embedded steel reinforcement.

Exposure of reinforced concrete to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions, present in deicing salts, seawater and other associated sources, into reinforced concrete can cause steel corrosion if oxygen and moisture are available to sustain the reaction. Chlorides dissolved in water can penetrate through sound concrete or reach the steel through cracks.

No other contaminant is documented as extensively in the literature as a cause of corrosion of metals in concrete than chloride ions. The risk of corrosion increases as the chloride content of concrete increases. For Hartley Bridge, the major concern is the extent of any existing chloride within the various concrete structural elements. While the levels are assessed during this survey, as the concrete is continually exposed to the natural environments and weathering, the level of chloride in the concrete could increase with time.

To assess potentially chloride-contaminated concrete, it is necessary to determine the concentration of chloride ions at various depths in order to determine the likelihood of corrosion of the reinforcement steel. To do this dust samples are taken from incremental depths. As specified by Roughan O'Donovan, this was to be carried out in three depths (5-25mm, 25-50mm & 50-75mm). Note the first 5mm drilling are normally discarded as being non-representative. Care was taken to ensure all drilling dust was collected. This is important as studies have shown that more chloride is contained in the finer component of the dust.

In line with the Irish concrete standard (EN 206), the chloride content as a percentage of cement is to be below the maximum allowable of 0.4% for concrete mixes containing embedded steel. From the dust samples tested at 8 locations, all results are below this maximum allowable of 0.4%.

4.4 Steel Beam Testing

An essential component of the Hartley Bridge survey was the condition of the steel within the bridge. This focus is due to the prevalence of steel beams within the longitudinal and transverse beams as well as the bridge wing wall.

Appendix G of this report includes the test results for the different tests completed.

The main finding is that the steel beams within the RC beams (either longitudinal / transverse or wing wall) had a yield of 271 MPA and a UTS of 459 MPA.

4.5 Steel Reinforcement Scanning & Trial Pit / Trench

Appendix E of this report details in full the findings of the survey works at Hartley Bridge. This included the following findings:

- No waterproofing on the top of deck slab or expansion joints present on Hartley Bridge.
- No services were identified in the make-up of the bridge.
- At the position of bridge piers, there is links between the deck slab and transverse beam with steel straps (25mm wide and 4/5mm thick) at consistent intervals and reinforcement bars found in some cases.
- Similar straps are found linking the bridge wing wall with the longitudinal edge beams. Appendix E illustrates the positioning of these.
- The two bridge edge beams are made up of steel beams encased in concrete. These are supported with steel straps. The straps are either diagonally supporting at piers or vertical in mid span.
- The diagonal support straps at piers appears to have been the beginning of deterioration by corrosion on the bridge. In many cases these support straps are completely visible due to spalling and are also in many cases completed eroded away on the inner side of the bridge. The vertical straps appear to have more concrete cover and are less are pronounced in their deterioration.
- The vertical straps come directly under the beams and turn back up. The diagonal straps came half way down the beam and turned into it. It appears to have been welded onto it.
- The transverse beams are also made up of two steel beams incased in concrete. The main difference is that those beams at pier locations also have two 20mm diameter smooth reinforcement bars as additional support. The steel beams in the transverse beams sit directly on top of the steel beams in the edge beams.
- The main deck slab is made up of 12mm diameter smooth reinforcement bars running longitudinally to the bridge. They are spaced at consistent readings with moderate concrete cover. In some cases (mid-span) the bars are corroded and have led to concrete spalling. The worst feature of the deck slab is the individual transverse bar spaced roughly half way between each transverse beam. In many cases the concrete cover is extremely low. No doubt corrosion got to this bar first and weakened the concrete around it which then spread to the longitudinal reinforcement bars.
- The column is made up of six 20mm diameter smooth reinforcement bars with 5mm diameter links are consistent spacings. These are largely in good condition. Additional reinforcement bars provide further support. Details of these is found in Appendix E of this report.
- The diagonal support beams are made up of found 12mm diameter smooth reinforcement bars with 5mm diameter links at consistent spacings.
- The wing wall of the bridge has steel reinforcement from the edge beams running through the wall and connecting to two steel beams placed at the top of the wall. Additional reinforcement bars play supporting roles to this. All is detailed in Appendix E of this report.

4.6 Half Cell Potential & Resistivity

An essential component of the survey of the concrete at Hartley Bridge was the completion of some half-cell and resistivity tests on the concrete surfaces to assess if there was any potential for corrosion or if corrosion was active within reinforcement bars currently not visible.

Corrosion of steel in concrete is one of the major problems with respect to the durability of reinforced concrete structures. The majority of concrete structures perform well even after a long period of use in normal environments. However, there are various reinforced concrete structures important for our infrastructure, especially bridges and buildings, which exhibit premature damage due to environmental actions (EN 206).

In contrast to mechanical actions (load, wind, etc.) the environmental actions are not reversible and accumulate hazardous components (such as chloride ions) in the concrete. A high percentage of the damages is caused by insufficient planning, wrong estimation of severity of environmental actions and by bad workmanship and thus many of these structures need to be repaired after a short service life.

Half-cell potential measurements can be performed on structures with ordinary or stainless steel reinforcement. Corrosion of prestressing steel in concrete can be assessed in the same way. Prestressing steel in the ducts of posttensioned cables cannot be assessed.

Half-cell potential measurements are suitable mainly on reinforced concrete structures exposed to the atmosphere. The method can be applied regardless of the depth of concrete cover and the rebar size. Half-cell potential measurements will indicate corroding rebars not only in the most external layers of reinforcement facing the references electrode but also in greater depth. The method can be used at any time during the life of a structure and in any kind of climate providing the temperature is higher than +2°C. Hal-cell potential measurements should be taken only on a free concrete surface. The presence of isolating layers (asphalt, organic coatings or paints etc.) may make measurements erroneous or impossible.

In addition to half-cell potential surveying of concrete, resistivity measurements of the same concrete material provide further information on the potential for further corrosion taking or to take place. Corrosion of reinforcing steel is an electro-chemical process. For corrosion of the steel to occur a current must pass between the anodic and cathodic regions of the concrete. The electrical resistivity of the concrete affects the flow of ions and the rate at which corrosion can occur. A higher concrete resistivity decreases the flow; an empirical relationship between corrosion rate and resistivity has been determined from measurements on actual structures.

Electrical resistivity measurement techniques are becoming popular among consulting / design engineers for the quality assessment and durability assessment of concrete. The concept of durability of concrete depends largely on the properties of its microstructure, such as pore size distribution and the shape of the interconnections (that is, tortuosity). A finer pore network, with less connectivity, leads to lower permeability. A porous microstructure with larger degree of interconnections, on the other hand, results in higher permeability and reduced durability in general. The principal idea behind most electrical resistivity techniques is to somehow quantify the conductive properties of the microstructure of concrete. Overall, the electrical resistivity of concrete can be described as the ability of concrete to withstand the transfer of ions subjected to an electrical field. In this context, resistivity measurement can be used to assess the size and extent of the interconnectivity of pores.

Various approaches for measuring resistivity are available but the four-probe device is the most suitable. Modern devices are spring-loaded and are applied directly to the surface. A current is applied between the two outer probes and the potential difference measured between the two inner probes. Resistivity measurement is useful for identifying areas of reinforced concrete at risk from corrosion. It should not be considered in isolation but used in conjunction with other techniques such as half-cell potential. BHP employed the use of the latest version of Proceq's Resipod with 50mm spacings between the four probes.

Appendix F of this report details the findings of all half-cell and resistivity results found at Hartley Bridge. A summary of these reports is as follows:

	Half-Cell			**Resistivity**		
Test	Range	Mean	Standard Deviation	Min	Max	Mean
1	-207 to -295	-260.0	18.3	53.4	75.4	65.6
2	-5 to -218	-78.7	59.4	286	662	463.3
3	-215 to -310	-245.7	18.9	178	838	520.9
4	-119 to -235	-169.5	30.6	324	730	494.3

Considering the relatively low levels of half-cell and resistivity values found it is surprising that there is such widespread concrete spalling and steel corrosion occurring at Hartley Bridge. However, it must be point out that:

- The worse values were found in the deck slab at mid span where many of the reinforcement bars were visible. At other locations of half-cell and resistivity tests this was not widely the case.
- Non-exposed reinforcement bars that were encased in concrete where visibly in good condition and free from excessive corrosion / corrosion staining when broken out.

5.0 Conclusions

From the structural investigation completed by BHP Laboratories at Hartley Bridge, the following conclusions can be drawn:

- Core 1 and 3 come from the main concrete deck slab of the bridge. Both cores seem to indicate good quality concrete with a mean concrete core strength result of 46.4N/mm² with and a mean density of 2370kg/m³.
- Core 2 comes from the screed that was placed directly on top of the bridge deck slab at location VC 1. The core had a strength of 30.7N/mm² with and a density of 2150kg/m³.
- Cores 4 - 7 were horizontal cores that came from either the bridge wing wall (Core 4) or the RC piers at two locations (Core 4 – 7). The pier cores seem to indicate a reasonably high voids of 5% with the visual description of the cores identifying "poor compaction". The horizontal concrete cores had a mean concrete core strength result of 37.5N/mm² with and a mean density of 2400kg/m³.
- In assessing the in-situ compressive strength of the concrete on Hartley Bridge, we must consider the methodology outlined in BS EN 13791: 2007 "Assessment of in-situ compressive strength in structures and precast concrete components".
    - The assessment of in-situ compressive strength directly from core tests constitutes the reference method. The test data produced from core tests can be used to estimate the in-situ characteristic strength and corresponding strength class according to EN 206.
    - In accordance with BS EN 13791: 2007 section 7, BHP ensured that cores were taken, examined and prepared in accordance with EN 12504-1 and were tested in accordance with EN 12390-3.
    - For the purpose of drawing conclusions from the data, we use Approach B from section 7.3.1 of BS EN 13791: 2007. This approach applies were 3 to 14 cores are available. It determines the in-situ compressive strength as the lower result obtained from use of the following formulas:
        - $f_{ck,is} = f_{m(n),is} - k$ (formula 1)
        - $f_{ck,is} = f_{is,lowest} + 4$ (formula 2)
    - Based on these formulas, the following in-situ strengths have been determined:

Formula	Deck Slab	Wall / Pier
Formula 1	39.4 N/mm² *	30.5 N/mm²
Formula 2	49.5 N/mm²	39.8 N/mm²

* Only 2 results available not the minimum of 3 as per EN13791

- As per the above and Table 1 of BS EN 13791: 2007, the compressive strength class of the concrete in the deck slab would be approximately a C35/45 mix. The compressive strength class of the concrete in the wall / piers would be approximately a C30/37.
- The highest depth of carbonation was found in the deck slab over land. The carbonation depth of >20mm is comparable to the concrete cover and is therefore a concern that further corrosion and concrete spalling will occur.
- In line with the Irish concrete standard (EN 206), the chloride content as a percentage of cement is to be below the maximum allowable of 0.4% for concrete mixes containing embedded steel. From the dust samples tested at 8 locations, all results are below this maximum allowable of 0.4%.
- Based on one sample from the bridge wing wall, the steel beams within the RC beams (either longitudinal / transverse or wing wall) had a yield of 271 MPA and a UTS of 459 MPA.
- The half-cell and resistivity test results did not indicate widespread worrying levels of either. Some of the resistivity results were much higher than would be expected. BHP must note that days after we conducted the survey works at Hartley Bridge, similar survey work on a pier yielded a much more consistent relationship between the half-cell and resistivity – particularly for very corroded sections of reinforced concrete. This is noted to confirm our satisfaction with the instrument being used.

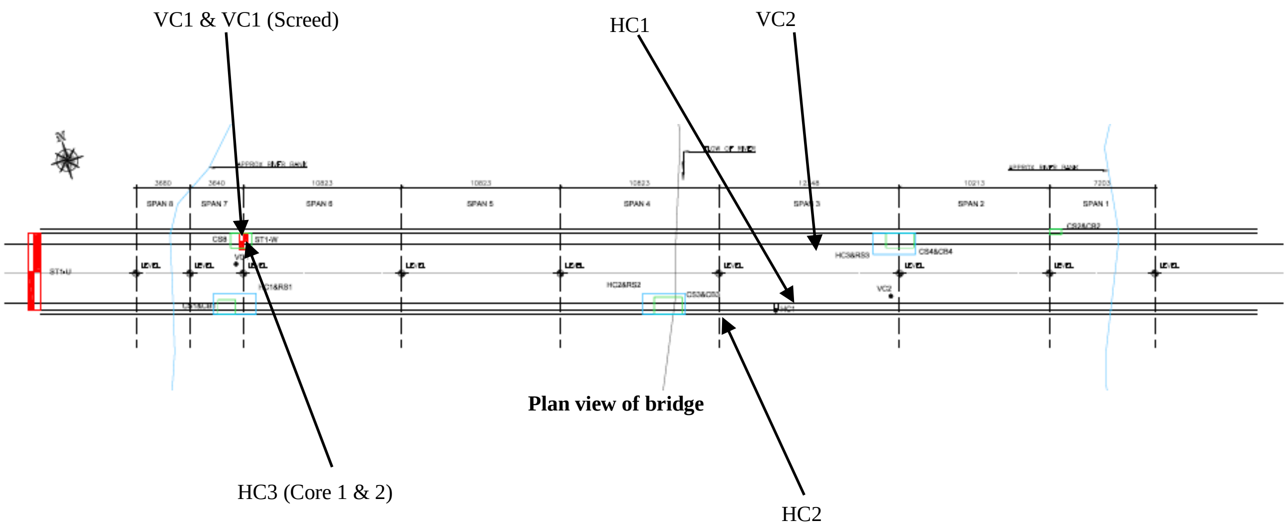
6.0 Recommendations

- Assuming that design calculations determined by Roughan O'Donovan can allow the continued use of Hartley Bridge with weight restriction, a comprehensive rehabilitation programme is required to prevent further corrosion/spalling. This would focus on the underside of the bridge and encompass all aspects of reinforced concrete within the structure.
- Concrete spalling should be repaired in the following/similar manner:
  - Remove all loose and poor concrete.
  - Clean the exposed steel.
  - Apply one coat of Sika MonoTop 610 primer.
  - Infill with Sika MonoTop 612.
  - Once all repairs are completed apply 3 coats of Ferrogard 903 for corrosion protection.
- For Hartley Bridge, consideration should be given to applying a Ferrogard 903 corrosion protection (or similar) to the entire set of bridge concrete pillars and support beams. This will help to keep any potential spalling from occurring or certainly delay the process. Such a coating will limit the amount of moisture that can penetrate through the concrete and corrode the steel reinforcement.
- An inspection program should be development for the maintenance of the bridge after renewal works are completed. This should be drawn up in accordance with NRA Specification requirements. Such an inspection program should be conducted every 5 years.
- Lastly, to prevent moisture penetrating from above the bridge, consideration should be given to applying a waterproofing layer to the top of slab / intersection of wing wall and slab along the bridge. This would be a much more difficult aspect of rehabilitation works as any major civil work would necessitate the use of heavy plant on the structure. BHP note here that the use of a compaction plate on the mid span of the bridge during reinstatement works as part of the structural investigation led to an alarming level of dust / pieces of concrete falling off the soffit. This was due to the vibrations of the plate. An alternative method of drainage may be sufficient to ensure rain water run-off is quick and does not penetrate down into the slab.

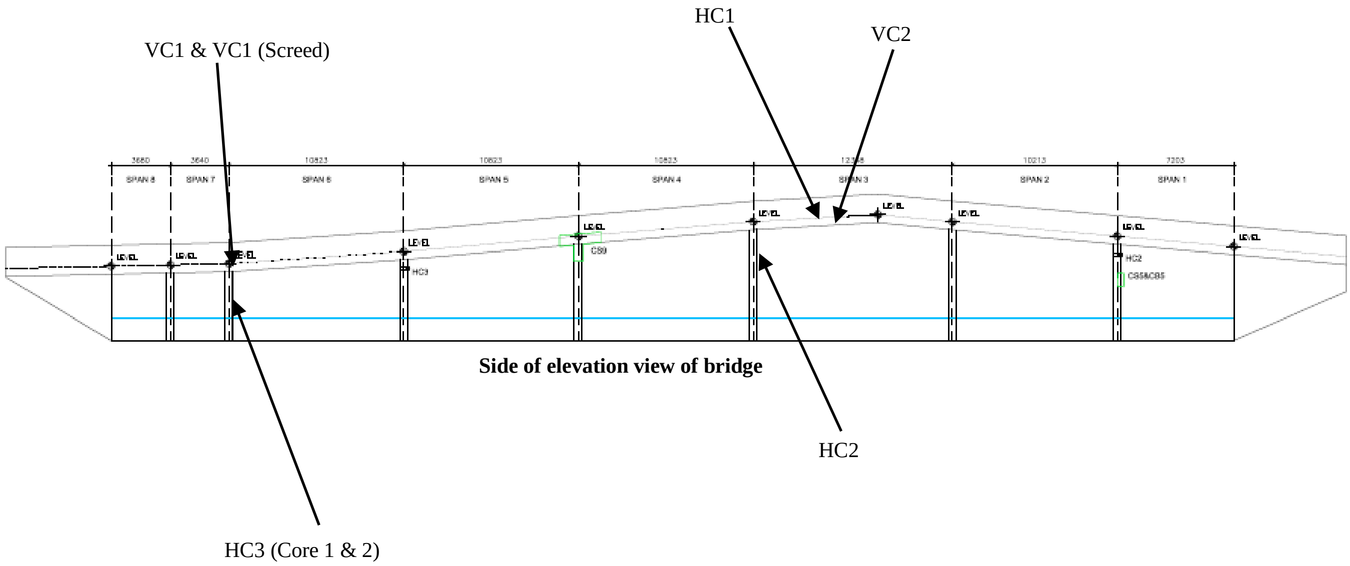
Appendix A

Core Reports

Core Locations



Plan view of bridge



Side of elevation view of bridge

Form No.: BHP/MTI/0170 1.1 27/09/06

TEST REPORT

Analysing
Testing
Consulting
Calibration

Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-1
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

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New Road
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Ireland
Tel +353 61 455399
Fax +353 61 455447
E Mail jamespurcell@bhp.ie

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.	:	VC1
Location	:	Vertical Core 1
Coring Date	:	11/04/2017
Condition of specimen when received	:	Good
Compaction of concrete	:	Good
Excess Voids	:	3.0%
Honeycombing	:	No
Presence of cracks	:	No
End of core used as datum	:	Top
Type of aggregate	:	Crushed Rock
Maximum nominal size of aggregate	:	28mm
Drilling Direction	:	Vertical
Method of determining volume	:	Displacement
Method of end preparation	:	Sawn & Capped
Distribution of materials	:	Even
Ribbing on core surface	:	None
Flatness	:	Pass
Perpendicularity	:	Pass
Straightness	:	Pass
Surface condition at time of test	:	Dry
Appearance of concrete/type of failure	:	Satisfactory
Average Diameter	:	104mm
Maximum length of specimen, as received	:	116mm
Minimum length of specimen, as received	:	94mm
Density of the specimen, as received	:	2360 kg/m³
Length after end preparation	:	102mm
Diameter after end preparation	:	104mm
Length / diameter ratio of specimen	:	0.98
Age of specimen	:	Unknown
Reinforcement in test specimen: Size	:	N/A
Position	:	N/A

Form No.: BHP/MTI/0170 1.1 27/09/06

BHP Ref.: 17/05/138-1

Results:

Max Load(kN)	:	401.9
Compressive Strength (N/mm2)	:	47.3

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 47.3 N/mm² +/- 5.5 N/mm².

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell

Deputy Laboratory Technical Manager

For and on behalf of BHP Laboratories

Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.

Sampling details where supplied are held on file.

TEST REPORT

Analysing
Testing
Consulting
Calibration

BHP
New Road
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Limerick
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E Mail jamespurcell@bhp.ie

Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-2
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.		:	VC1 (Screed - top of concrete deck slab)
Location		:	Vertical Core 1
Coring Date		:	11/04/2017
Condition of specimen when received		:	Good
Compaction of concrete		:	Good
Excess Voids		:	3.0%
Honeycombing		:	No
Presence of cracks		:	No
End of core used as datum		:	Top
Type of aggregate		:	Crushed Rock
Maximum nominal size of aggregate		:	10mm
Drilling Direction		:	Vertical
Method of determining volume		:	Displacement
Method of end preparation		:	Sawn & Capped
Distribution of materials		:	Even
Ribbing on core surface		:	None
Flatness		:	Pass
Perpendicularity		:	Pass
Straightness		:	Pass
Surface condition at time of test		:	Dry
Appearance of concrete/type of failure		:	Satisfactory
Average Diameter		:	104mm
Maximum length of specimen, as received		:	42mm
Minimum length of specimen, as received		:	35mm
Density of the specimen, as received		:	2150 kg/m³
Length after end preparation		:	48mm
Diameter after end preparation		:	104mm
Length / diameter ratio of specimen		:	0.46
Age of specimen		:	Unknown
Reinforcement			
in test specimen:	Size	:	N/A
	Position	:	N/A

Form No.: BHP/MTI/0170 1.1 27/09/06

BHP Ref.: 17/05/138-2

Results:

Max Load(kN)	:	260.5
Compressive Strength (N/mm2)	:	30.7

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 30.7 N/mm² +/- 3.5 N/mm².

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell
Deputy Laboratory Technical Manager
For and on behalf of BHP Laboratories

Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.
Sampling details where supplied are held on file.

TEST REPORT

Analysing
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Consulting
Calibration

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Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-3
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.	:	VC2
Location	:	Vertical Core 2
Coring Date	:	11/04/2017
Condition of specimen when received	:	Good
Compaction of concrete	:	Good
Excess Voids	:	1.0%
Honeycombing	:	No
Presence of cracks	:	No
End of core used as datum	:	Top
Type of aggregate	:	Crushed Rock
Maximum nominal size of aggregate	:	28mm
Drilling Direction	:	Vertical
Method of determining volume	:	Displacement
Method of end preparation	:	Sawn & Capped
Distribution of materials	:	Even
Ribbing on core surface	:	None
Flatness	:	Pass
Perpendicularity	:	Pass
Straightness	:	Pass
Surface condition at time of test	:	Dry
Appearance of concrete/type of failure	:	Satisfactory
Average Diameter	:	104mm
Maximum length of specimen, as received	:	100mm
Minimum length of specimen, as received	:	95mm
Density of the specimen, as received	:	2370 kg/m³
Length after end preparation	:	101mm
Diameter after end preparation	:	104mm
Length / diameter ratio of specimen	:	0.97
Age of specimen	:	Unknown
Reinforcement		
in test specimen: Size	:	N/A
Position	:	N/A

Form No.: BHP/MTI/0170 1.1 27/09/06

BHP Ref.: 17/05/138-3

Results:

Max Load(kN)	:	386.7
Compressive Strength (N/mm2)	:	45.5

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 45.5 N/mm² +/- 5.5 N/mm².

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell

Deputy Laboratory Technical Manager

For and on behalf of BHP Laboratories

Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.

Sampling details where supplied are held on file.

TEST REPORT

Analysing
Testing
Consulting
Calibration

Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-4
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

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DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.	:	HC1
Location	:	Horizontal Core 1
Coring Date	:	11/04/2017
Condition of specimen when received	:	Good
Compaction of concrete	:	Good
Excess Voids	:	3.0%
Honeycombing	:	No
Presence of cracks	:	No
End of core used as datum	:	Top
Type of aggregate	:	Crushed Rock
Maximum nominal size of aggregate	:	28mm
Drilling Direction	:	Horizontal
Method of determining volume	:	Displacement
Method of end preparation	:	Sawn & Capped
Distribution of materials	:	Even
Ribbing on core surface	:	None
Flatness	:	Pass
Perpendicularity	:	Pass
Straightness	:	Pass
Surface condition at time of test	:	Dry
Appearance of concrete/type of failure	:	Satisfactory
Average Diameter	:	104mm
Maximum length of specimen, as received	:	130mm
Minimum length of specimen, as received	:	130mm
Density of the specimen, as received	:	2430 kg/m³
Length after end preparation	:	101mm
Diameter after end preparation	:	104mm
Length / diameter ratio of specimen	:	0.97
Age of specimen	:	Unknown
Reinforcement in test specimen: Size	:	N/A
Position	:	N/A

BHP Ref.: 17/05/138-4

Results:

Max Load(kN)	:	340.1
Compressive Strength (N/mm2)	:	40.1

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 40.1 N/mm² +/- 5 N/mm².

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell

Deputy Laboratory Technical Manager

For and on behalf of BHP Laboratories

Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.

Sampling details where supplied are held on file.

TEST REPORT

Analysing
Testing
Consulting
Calibration

Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-5
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

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Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.	:	HC2
Location	:	Horizontal Core 2
Coring Date	:	11/04/2017
Condition of specimen when received	:	Good
Compaction of concrete	:	Good
Excess Voids	:	5% (poor compaction - concrete "going off")
Honeycombing	:	No
Presence of cracks	:	No
End of core used as datum	:	Top
Type of aggregate	:	Crushed Rock
Maximum nominal size of aggregate	:	28mm
Drilling Direction	:	Horizontal
Method of determining volume	:	Displacement
Method of end preparation	:	Sawn & Capped
Distribution of materials	:	Even
Ribbing on core surface	:	None
Flatness	:	Pass
Perpendicularity	:	Pass
Straightness	:	Pass
Surface condition at time of test	:	Dry
Appearance of concrete/type of failure	:	Satisfactory
Average Diameter	:	104mm
Maximum length of specimen, as received	:	165mm
Minimum length of specimen, as received	:	145mm
Density of the specimen, as received	:	2350 kg/m³
Length after end preparation	:	103mm
Diameter after end preparation	:	104mm
Length / diameter ratio of specimen	:	0.99
Age of specimen	:	Unknown
Reinforcement		
in test specimen: Size	:	N/A
Position	:	N/A

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BHP Ref.: 17/05/138-5

Results:

Max Load(kN)	:	303.9
Compressive Strength (N/mm2)	:	35.8

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 35.8 N/mm² +/- 4.5 N/mm².

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell

Deputy Laboratory Technical Manager

For and on behalf of BHP Laboratories

Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.

Sampling details where supplied are held on file.

Form No.: BHP/MTI/0170 1.1 27/09/06

INAB ISO 17025 ACCREDITED TESTING DETAILED IN SCOPE REG NO.005T

TEST REPORT

Analysing
Testing
Consulting
Calibration

Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-6
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

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Tel +353 61 455399
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DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.	:	HC3 (Core 1)
Location	:	Horizontal Core 3
Coring Date	:	11/04/2017
Condition of specimen when received	:	Good
Compaction of concrete	:	Good
Excess Voids	:	5% (poor compaction - concrete "going off")
Honeycombing	:	No
Presence of cracks	:	No
End of core used as datum	:	Top
Type of aggregate	:	Crushed Rock
Maximum nominal size of aggregate	:	28mm
Drilling Direction	:	Horizontal
Method of determining volume	:	Displacement
Method of end preparation	:	Sawn & Capped
Distribution of materials	:	Even
Ribbing on core surface	:	None
Flatness	:	Pass
Perpendicularity	:	Pass
Straightness	:	Pass
Surface condition at time of test	:	Dry
Appearance of concrete/type of failure	:	Satisfactory
Average Diameter	:	104mm
Maximum length of specimen, as received	:	320mm
Minimum length of specimen, as received	:	320mm
Density of the specimen, as received	:	2410 kg/m³
Length after end preparation	:	103mm
Diameter after end preparation	:	104mm
Length / diameter ratio of specimen	:	0.99
Age of specimen	:	Unknown
Reinforcement		
in test specimen: Size	:	N/A
Position	:	N/A

BHP Ref.: 17/05/138-6

Results:

Max Load(kN)	:	313.4
Compressive Strength (N/mm2)	:	36.9

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 36.9 N/mm^2 +/- 4.5 N/mm^2.

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell

Deputy Laboratory Technical Manager

For and on behalf of BHP Laboratories

Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.

Sampling details where supplied are held on file.

Form No.: BHP/MTI/0170 1.1 27/09/06

TEST REPORT

Analysing
Testing
Consulting
Calibration

Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/138-7
		Order No:	Not Supplied
		Date Received:	12/04/2017
		Date Tested:	15/05/2017
		Test Specification:	EN 12504-1:2009
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Core

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

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DETERMINATION OF THE COMPRESSIVE STRENGTH OF A CONCRETE CORE TO BS EN 12504-1:2009

Core Ref.	:	HC3 (Core 2)
Location	:	Horizontal Core 3
Coring Date	:	11/04/2017
Condition of specimen when received	:	Good
Compaction of concrete	:	Good
Excess Voids	:	5% (poor compaction - concrete "going off")
Honeycombing	:	No
Presence of cracks	:	No
End of core used as datum	:	Top
Type of aggregate	:	Crushed Rock
Maximum nominal size of aggregate	:	28mm
Drilling Direction	:	Horizontal
Method of determining volume	:	Displacement
Method of end preparation	:	Sawn & Capped
Distribution of materials	:	Even
Ribbing on core surface	:	None
Flatness	:	Pass
Perpendicularity	:	Pass
Straightness	:	Pass
Surface condition at time of test	:	Dry
Appearance of concrete/type of failure	:	Satisfactory
Average Diameter	:	104mm
Maximum length of specimen, as received	:	320mm
Minimum length of specimen, as received	:	320mm
Density of the specimen, as received	:	2420 kg/m³
Length after end preparation	:	102mm
Diameter after end preparation	:	104mm
Length / diameter ratio of specimen	:	0.98
Age of specimen	:	Unknown
Reinforcement		
in test specimen: Size	:	N/A
Position	:	N/A

BHP Ref.: 17/05/138-7

Results:

Max Load(kN)	:	315.4
Compressive Strength (N/mm2)	:	37.1

Remarks:

The in situ compressive strength of the concrete as represented by the core, as supplied is 37.1 N/mm² +/- 4.5 N/mm².

Tested at BHP Laboratories Kileely Permanent Laboratory.

Authorised By:

James Purcell
Deputy Laboratory Technical Manager
For and on behalf of BHP Laboratories

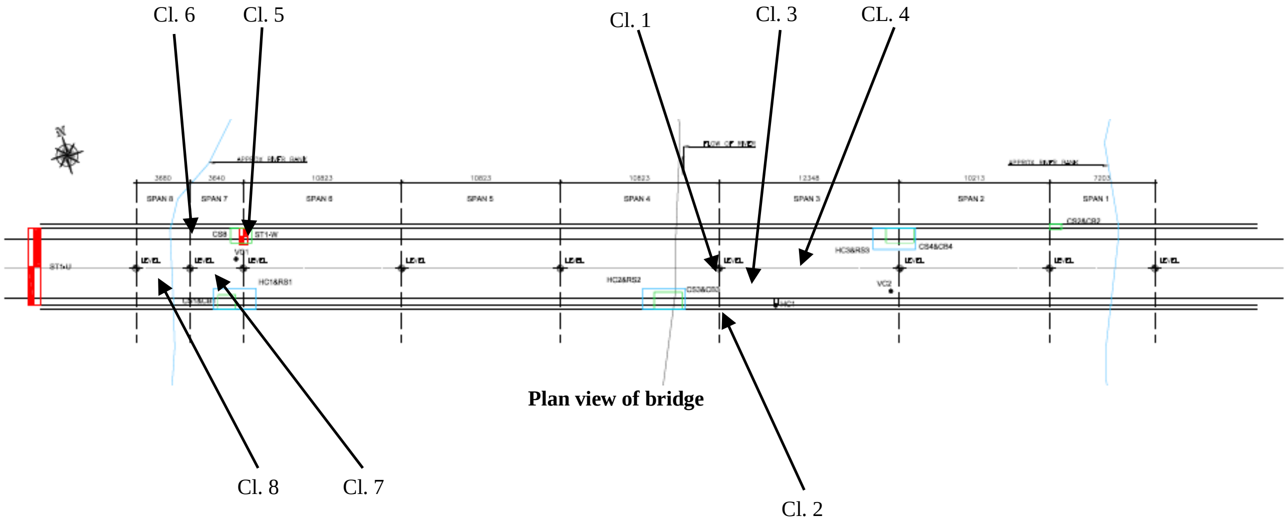
Issue Date: 8th June 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated,except in full and only with the permission of the test laboratory.
Sampling details where supplied are held on file.

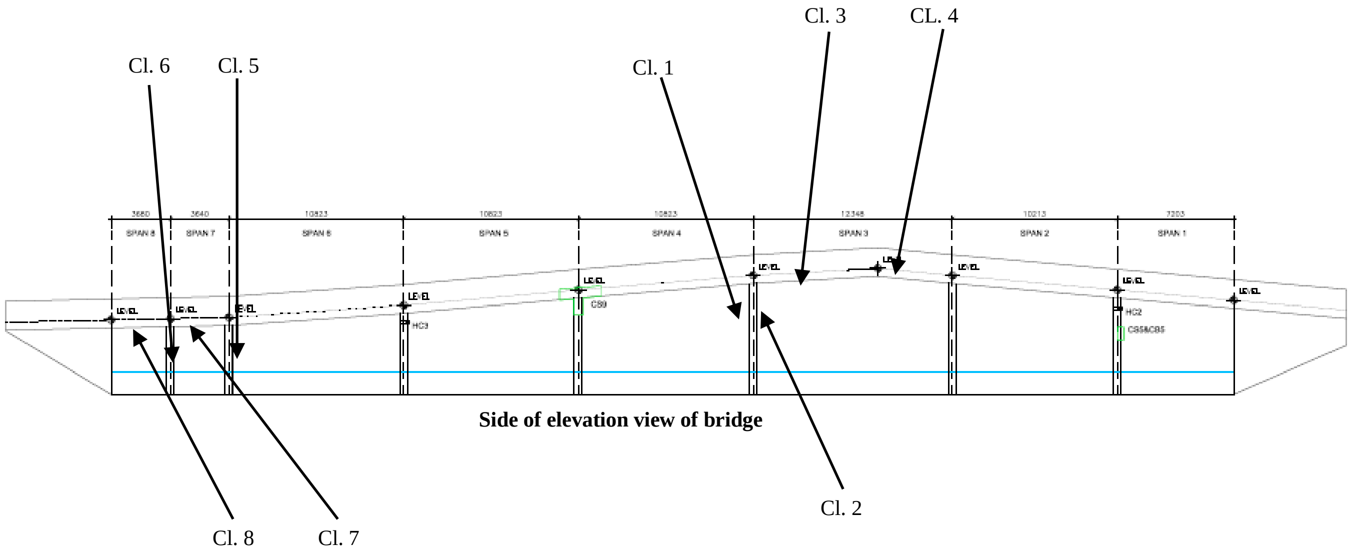
Appendix B

Carbonation Reports

Carbonation Test Locations



Plan view of bridge



Side of elevation view of bridge

TEST REPORT

Analysing
Testing
Consulting

Client: Leitrim County Council
Áras an Chontae
Carrick on Shannon
Co. Leitrim

F.T.A.O.: Mr. Michael Gallagher

BHP Ref. No.: 17/05/140
Order No: Not Supplied
Date Received: 12/04/2017
Date Tested: 12/04/2017
Test Spec.: Customer Spec.
Item: Dust sample

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Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

BHP Reference	Location References	Units	Carbonation	Notes
17/05/140-1	Test at Location CL 1. Inside face of diagonal support beam for column.	mm	2	N/A
17/05/140-2	Test at Location CL 2. Inside face of column at highest half cell level.	mm	3	N/A
17/05/140-3	Test at Location CL 3. Soffit of deck slab at highest half cell level.	mm	8	N/A
17/05/140-4	Test close to Location CL 3. Soffit of deck slab.	mm	7	N/A
17/05/140-5	Test at Location CL 4. Column (over land)	mm	15	N/A
17/05/140-6	Test at Location CL 5. Column (over land)	mm	14	N/A

Additional Information:
Indicator used is a 3% phenolphthalein mixture.

Authorised by:

James Purcell
Deputy Laboratory Technical Manager
BHP Laboratories Limited

Date of Issue: 8th June 2017

TEST REPORT

Analysing
Testing
Consulting

Client: Leitrim County Council
Áras an Chontae
Carrick on Shannon
Co. Leitrim

F.T.A.O.: Mr. Michael Gallagher

BHP Ref. No.: 17/05/140
Order No: Not Supplied
Date Received: 12/04/2017
Date Tested: 12/04/2017
Test Spec.: Customer Spec.
Item: Dust sample

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Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

BHP Reference	Location References	Units	Carbonation	Notes
17/05/140-7	Test at Location CL 8. Soffit of deck slab (over land)	mm	24	N/A
17/05/140-8	Test close to Location CL 8. Soffit of deck slab (over land)	mm	22	N/A

Additional Information:
Indicator used is a 3% phenolphthalein mixture.

Authorised by:

James Purcell
Deputy Laboratory Technical Manager
BHP Laboratories Limited

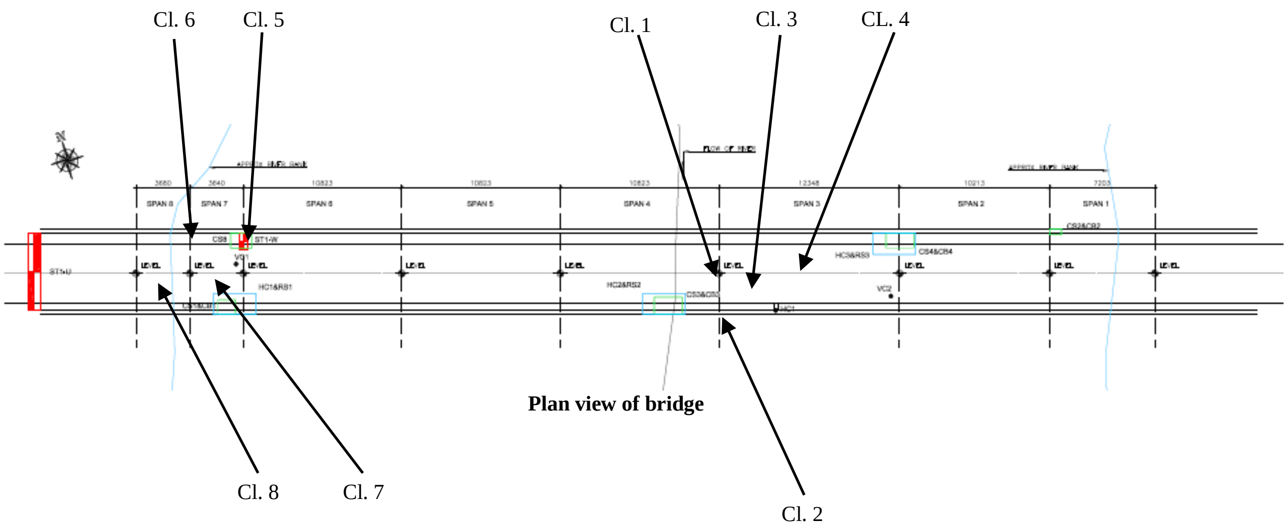
Date of Issue: 8th June 2017

Test results relate only to this/these items. This test report shall not be duplicated in full without the permission of the test laboratory.

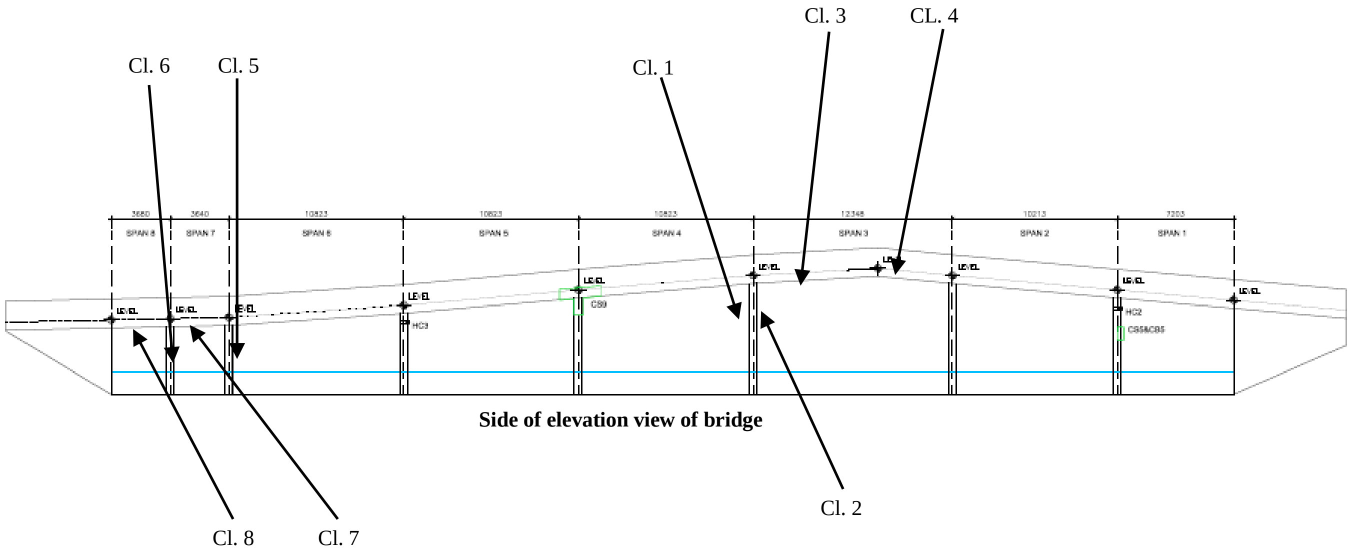
Appendix C

Chloride Content Reports

Chloride Test Locations



Plan view of bridge



Side of elevation view of bridge

TEST REPORT

Analysing
Testing
Consulting

Client: Leitrim County Council
Áras an Chontae
Carrick on Shannon
Co. Leitrim

F.T.A.O.: Mr. Michael Gallagher

BHP Ref. No.: 17/05/140
Order No: Not Supplied
Date Received: 12/04/2017
Date Tested: 15/05/2017
Test Spec.: Customer Spec.
Item: Dust sample

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Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

BHP Reference	Location References	Units	Chloride Content as % by mass of	
			Sample	Cement
17/05/140-1-1	Chloride Sample 1 (CL 1) (Chloride Content 5-25mm)	%	0.02	0.14
17/05/140-1-2	Chloride Sample 1 (CL 1) (Chloride Content 25-50mm)	%	0.02	0.14
17/05/140-1-3	Chloride Sample 1 (CL 1) (Chloride Content 50-75mm)	%	0.01	0.07
17/05/140-2-1	Chloride Sample 2 (CL 2) (Chloride Content 5-25mm)	%	0.04	0.29
17/05/140-2-2	Chloride Sample 2 (CL 2) (Chloride Content 25-50mm)	%	0.01	0.07
17/05/140-2-3	Chloride Sample 2 (CL 2) (Chloride Content 50-75mm)	%	0.01	0.07
17/05/140-3-1	Chloride Sample 3 (CL 3) (Chloride Content 5-25mm)	%	0.05	0.36
17/05/140-3-2	Chloride Sample 3 (CL 3) (Chloride Content 25-50mm)	%	0.04	0.29
17/05/140-3-3	Chloride Sample 3 (CL 3) (Chloride Content 50-75mm)	%	0.01	0.07
17/05/140-4-1	Chloride Sample 4 (CL 4) (Chloride Content 5-25mm)	%	0.02	0.14
17/05/140-4-2	Chloride Sample 4 (CL 4) (Chloride Content 25-50mm)	%	0.01	0.07
17/05/140-4-3	Chloride Sample 4 (CL 4) (Chloride Content 50-75mm)	%	0.01	0.07

Additional Information:

The Chloride Content is a Acid Soluble Chloride value.
The Sulphate Content as a % by mass of cement is based on an assumed cement content of 14%.
EN 206 states the Chloride Content as a % by mass of cement is recommended to be a maxium of 0.4% (containing embedded steel).

Authorised by:

James Purcell
Deputy Laboratory Technical Manager
BHP Laboratories Limited

Date of Issue: 8th June 2017

These tests were subcontracted to an approved accredited supplier.

Test results relate only to this/these items. This test report shall not be duplicated in full without the permission of the test laboratory.

TEST REPORT

Analysing
Testing
Consulting

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E Mail jamespurcell@bhp.ie

Client: Leitrim County Council
Áras an Chontae
Carrick on Shannon
Co. Leitrim

F.T.A.O.: Mr. Michael Gallagher

BHP Ref. No.: 17/05/140
Order No: Not Supplied
Date Received: 12/04/2017
Date Tested: 15/05/2017
Test Spec.: Customer Spec.
Item: Dust sample

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Sampling Certificate Provided: Yes

BHP Reference	Location References	Units	Chloride Content as % by mass of	
			Sample	Cement
17/05/140-5-1	Chloride Sample 5 (CL 5) (Chloride Content 5-25mm)	%	0.01	0.07
17/05/140-5-2	Chloride Sample 5 (CL 5) (Chloride Content 25-50mm)	%	0.01	0.07
17/05/140-5-3	Chloride Sample 5 (CL 5) (Chloride Content 50-75mm)	%	0.01	0.07
17/05/140-6-1	Chloride Sample 6 (CL 6) (Chloride Content 5-25mm)	%	0.02	0.14
17/05/140-6-2	Chloride Sample 6 (CL 6) (Chloride Content 25-50mm)	%	0.01	0.07
17/05/140-6-3	Chloride Sample 6 (CL 6) (Chloride Content 50-75mm)	%	0.01	0.07
17/05/140-7-1	Chloride Sample 7 (CL 7) (Chloride Content 5-25mm)	%	0.02	0.14
17/05/140-7-2	Chloride Sample 7 (CL 7) (Chloride Content 25-50mm)	%	0.01	0.07
17/05/140-7-3	Chloride Sample 7 (CL 7) (Chloride Content 50-75mm)	%	0.01	0.07
17/05/140-8-1	Chloride Sample 8 (CL 8) (Chloride Content 5-25mm)	%	0.04	0.29
17/05/140-8-2	Chloride Sample 8 (CL 8) (Chloride Content 25-50mm)	%	0.05	0.36
17/05/140-8-3	Chloride Sample 8 (CL 8) (Chloride Content 50-75mm)	%	0.01	0.07

Additional Information:

The Chloride Content is a Acid Soluble Chloride value.
The Sulphate Content as a % by mass of cement is based on an assumed cement content of 14%.
EN 206 states the Chloride Content as a % by mass of cement is recommended to be a maxium of 0.4% (containing embedded steel).

Authorised by:

James Purcell
Deputy Laboratory Technical Manager
BHP Laboratories Limited

Date of Issue: 8th June 2017

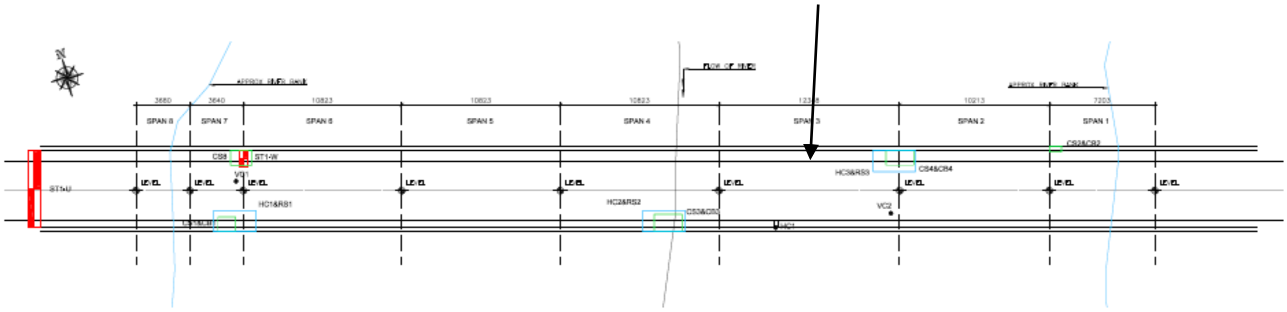
These tests were subcontracted to an approved accredited supplier.

Appendix D

Steel Tensile Test Report

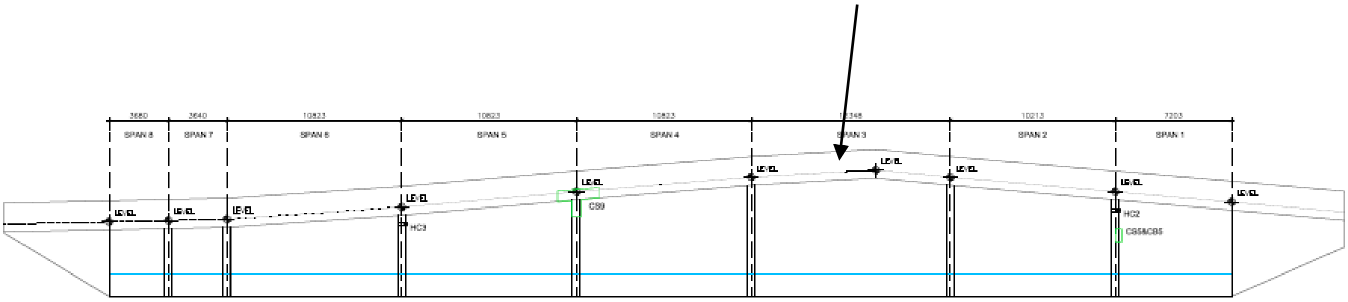
Steel Tensile Test Location

Tensile Sample taken from beam in top of wing wall



Plan view of bridge

Tensile Sample taken from beam in top of wing wall



Side of elevation view of bridge

Test Report

ISO 17025 INAB ACCREDITED TESTING DETAILED IN SCOPE REG NO.005T

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Calibrating

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Michael Gallagher
Leitrim County Council

BHP Ref No. MC 81536 17/05/114
Purchase order: **Leitrim County Council**
Recieved date: **08 May 2017**
Test Date. **24 May 2017**

Customer ref: **Hartley Bridge structural investigation**

Customer Instruction: **Relevant tests from a customer instruction**

Received Item(s): **1 x steel section**

Accredited tests below:

Ref	Test	Method	Type	Dimensions mm		CSA mm2	Yield MPA	UTS MPA	Elongation %	Remarks
1	Tensile M	EN ISO 6892-1:2009	Long	20.05	x 9.85	197.49	271	459	35.5	Fracture in Gage length

Authorised by **Additional information** Material specification Nil

Brian O'Brien
Technical manager
Date Issued: **24 May 2017**

Appendix E

Steel Reinforcement Survey & Summary of Trial Pits / Trenches

TEST REPORT

Analysing
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Account: Leitrim County Council
Áras an Chontae
Carrick on Shannon
Co. Leitrim

Customer: Mr. Michael Gallagher

BHP Ref No.: 17/05/141
Order No.: Not Supplied
Date Received: Not Applicable
Date Tested: 21/28th April 2017
Specification: Client Specification

Customer Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

Trial Pit / Trench & Reinforcement Survey

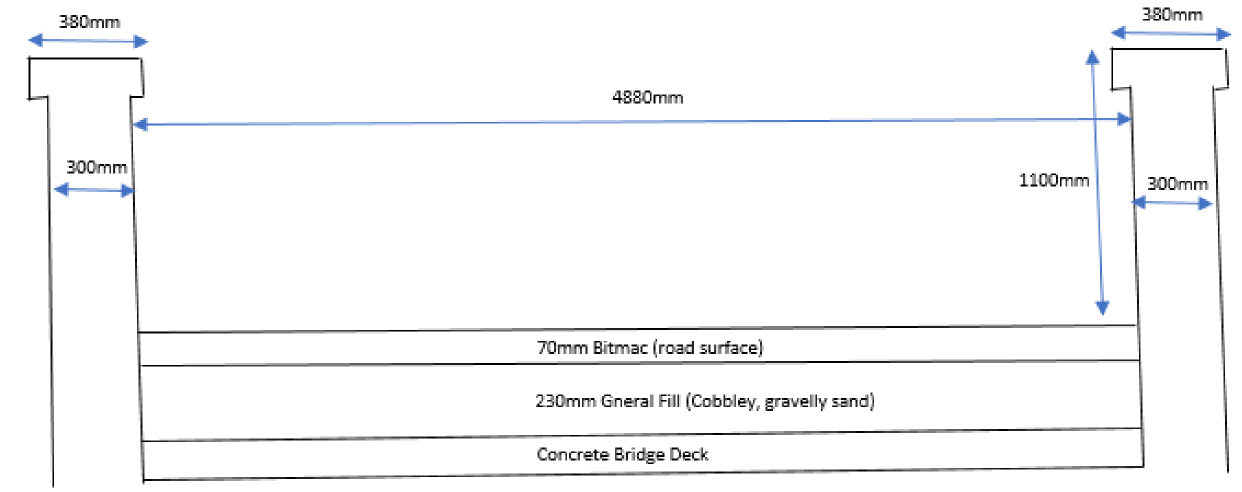
On Tuesday 18th, Wednesday 19th and Thursday 20th April 2017, BHP Laboratories visited Hartley Bridge. The purpose of these specific works was to conduct a series of destructive, non-destructive and measuring services throughout sample areas on the bridge. The aim of the works was to provide the client (Leitrim Co Co) with the necessary information to compile a structural assessment of the bridge. BHP were directed throughout the works by Roughan O'Donovan Consulting Engineers.

For the purpose of the investigation, BHP assumed bar sizes based on those given in drawings supplied. Due to noise constraints, BHP were not allowed to conduct the necessary breakouts to confirm size of bar, exact cover and associated calibrations readings for all areas. The presence of shear links was also not determined as a breakout was not permitted to establish the scanning profile of same.

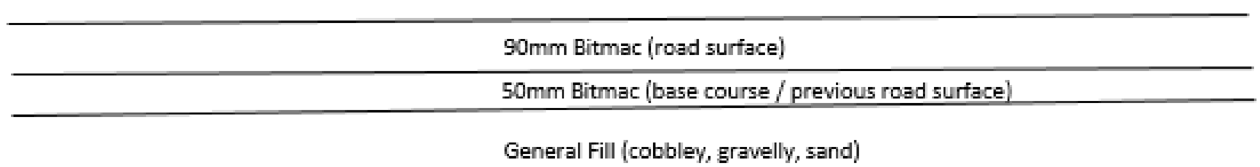
BHP conducted this reinforcement scanning using the latest technology from Proceq – Profometer 650 AI.

1.0 Bridge Investigative Slit Trench / Trial Pits

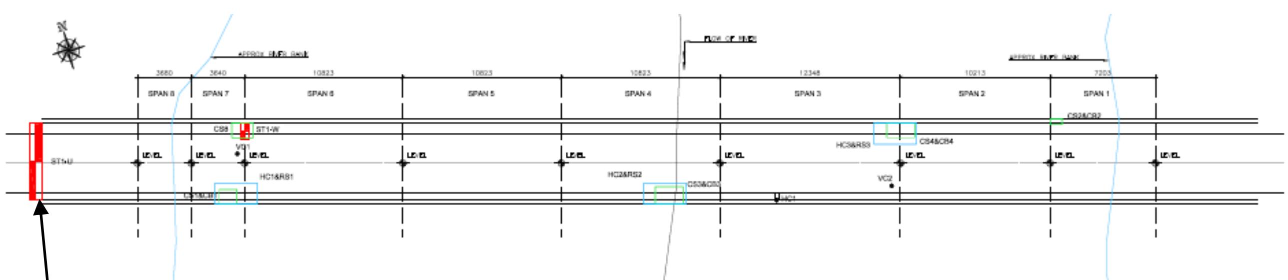
1.1 ST1-U



Sketch 1: Side of elevation view of bridge deck make-up (from west side of bridge facing east)

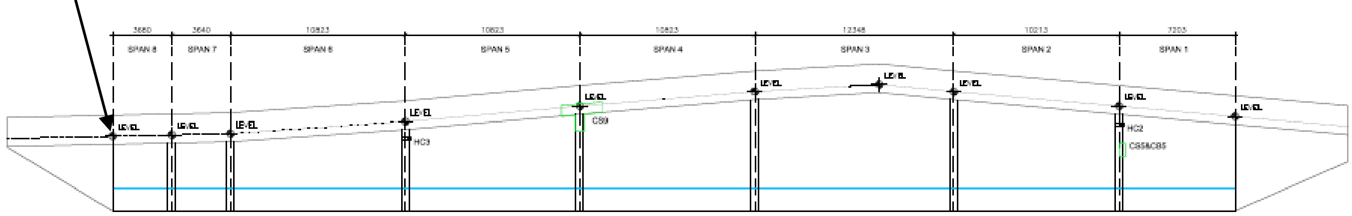


Side of elevation view of road make-up (from west side of bridge facing west)



Plan view of bridge

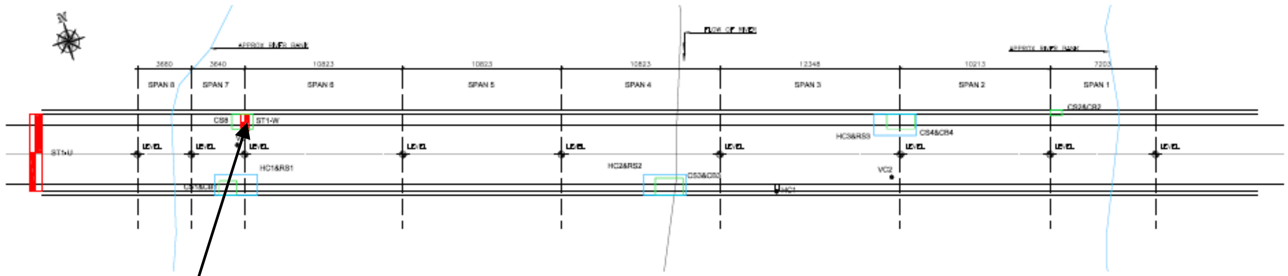
Slit Trench (ST1-U)



Side of elevation view of bridge

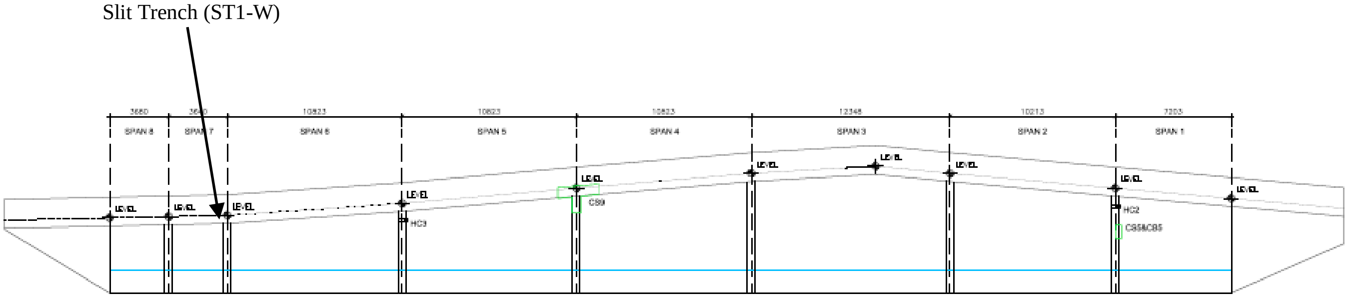
1.2 ST1-W & CS8

As part of the survey work required at locations ST1-W and CS8, BHP completed a trial pit on the north verge of the bridge (location confirmed below, photographs included). This trial pit was 800mm wide and 1600mm in length.



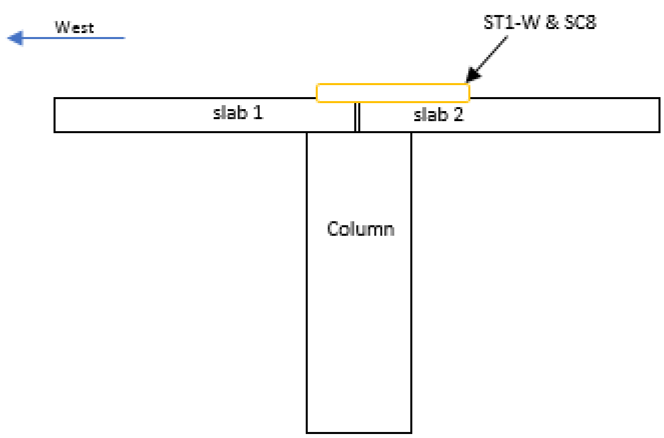
Plan view of bridge

Slit Trench (ST1-W)

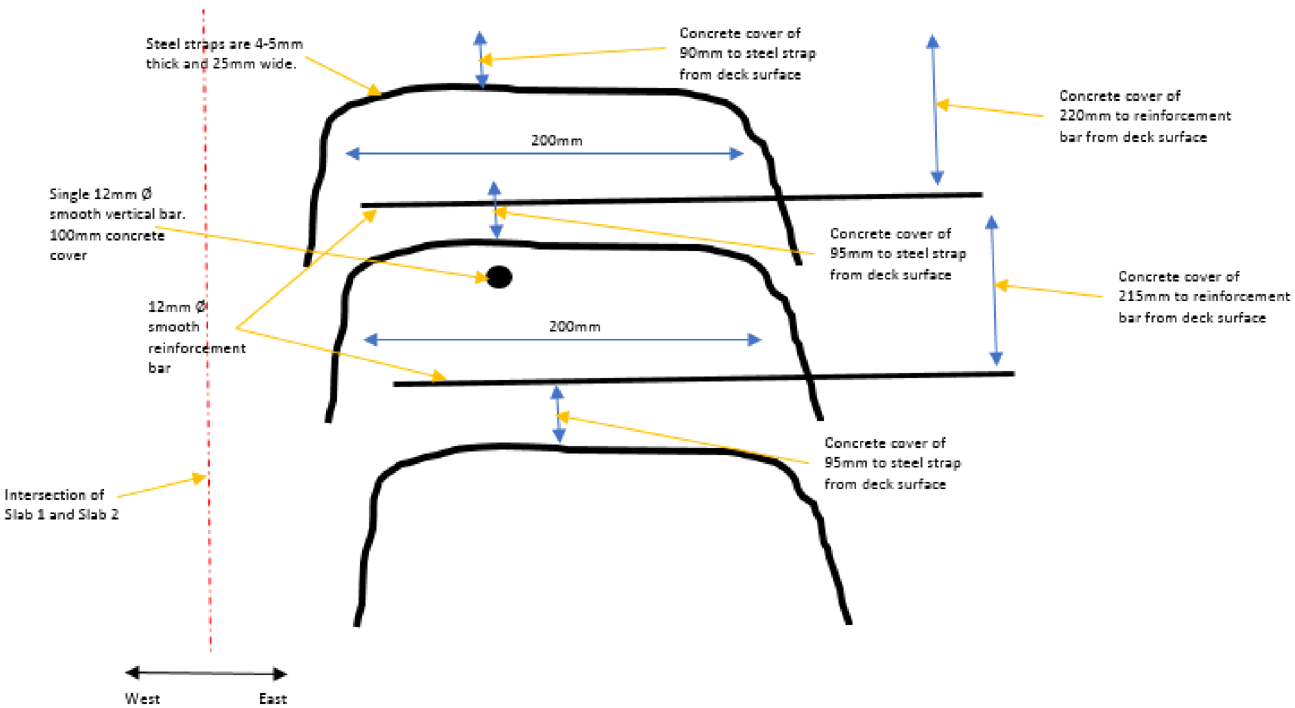


Side of elevation view of bridge

This trial pit was conducted directly above the bridge column. There was also a different deck slab on the west side of the bridge. This slab spans the first two columns (from west side). The slab placed directly beside this spans the remainder of the bridge. BHP did not find waterproofing on either deck slab.

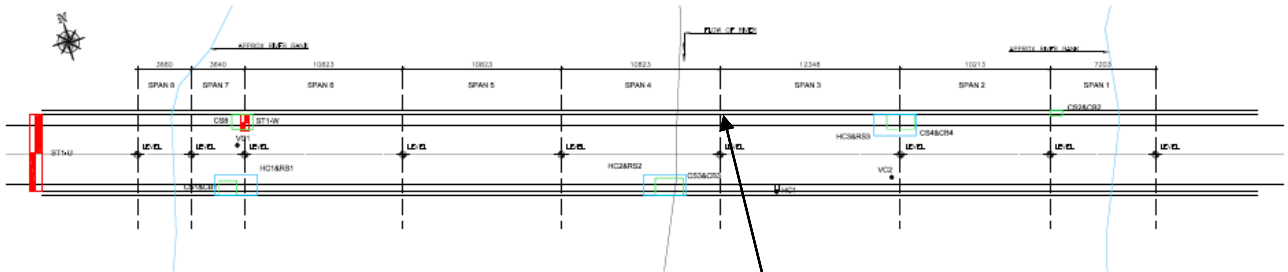


BHP scanned deck slab 1 at all available exposed space. There was no steel reinforcement detected. BHP then scanned deck slab 2. There were irregular reinforcement readings. In order to further investigate, BHP completed a trial pit into the concrete to expose the reinforcement present and to calibrate the scanning tool.


Steel straps are 4-5mm thick and 25mm wide.
Concrete cover of 90mm to steel strap from deck surface
Concrete cover of 220mm to reinforcement bar from deck surface
200mm
Single 12mm Ø smooth vertical bar. 100mm concrete cover
Concrete cover of 95mm to steel strap from deck surface
Concrete cover of 215mm to reinforcement bar from deck surface
12mm Ø smooth reinforcement bar
200mm
Concrete cover of 95mm to steel strap from deck surface
Intersection of Slab 1 and Slab 2
West
East

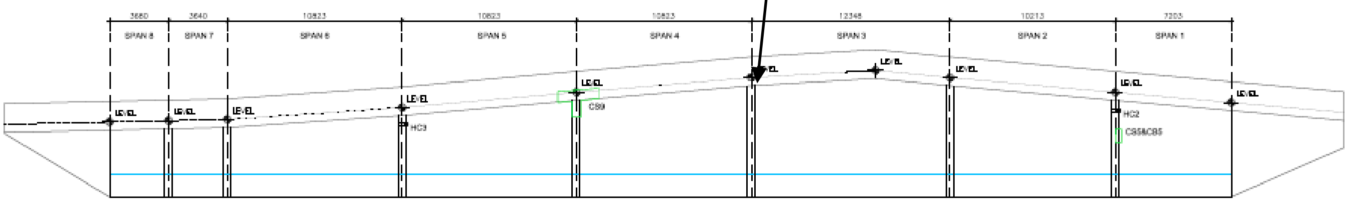
1.3 CS4 & CB4

As part of the survey work required at locations CS4 and CB4, BHP completed a trial pit on the top of the bridge surface (location confirmed below, photographs included). This trial pit was 700mm wide and 3000mm in length. In order to access the deck slab, the verge material (soil and grass) and road surface was removed. There is a layer of bitmac (road surfacing) of approx. 50mm at this point of the bridge. This is laid directly down on the bridge deck slab. There is no evidence of waterproofing on the bridge.



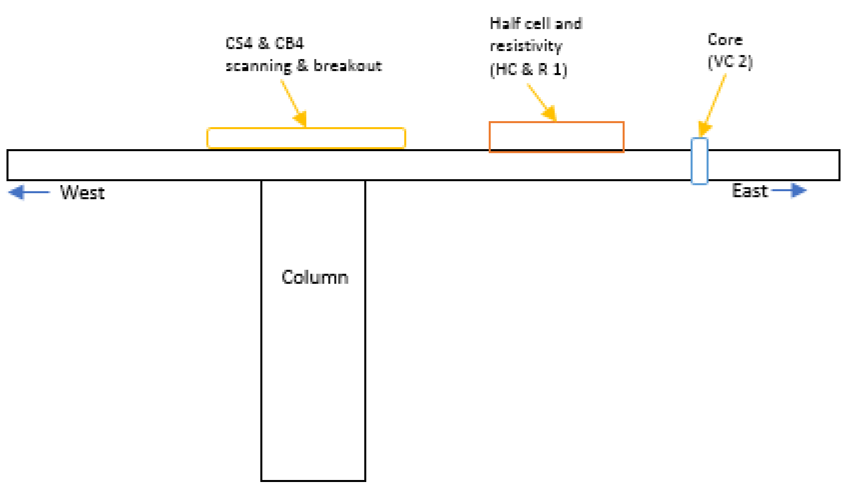
Plan view of bridge

Slit Trench (SC4 & CB4)

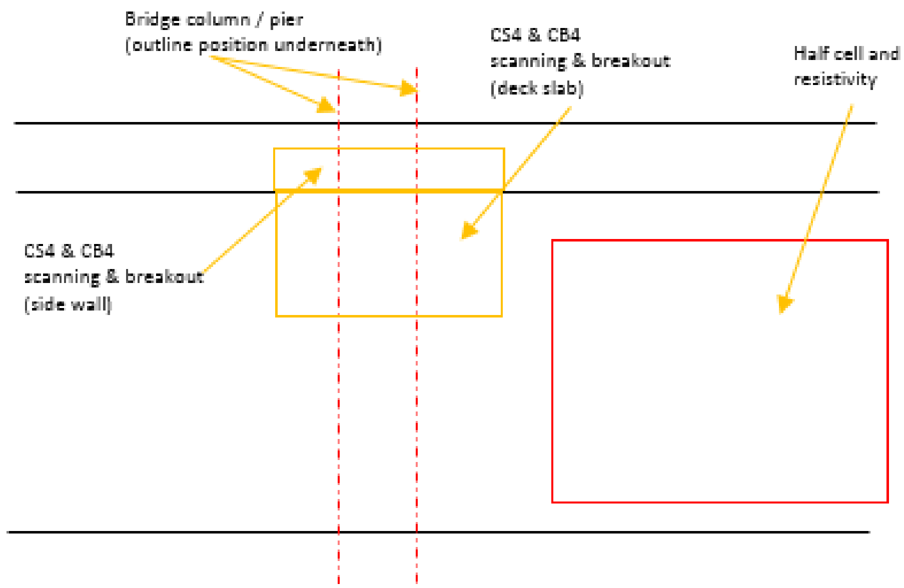


Side of elevation view of bridge

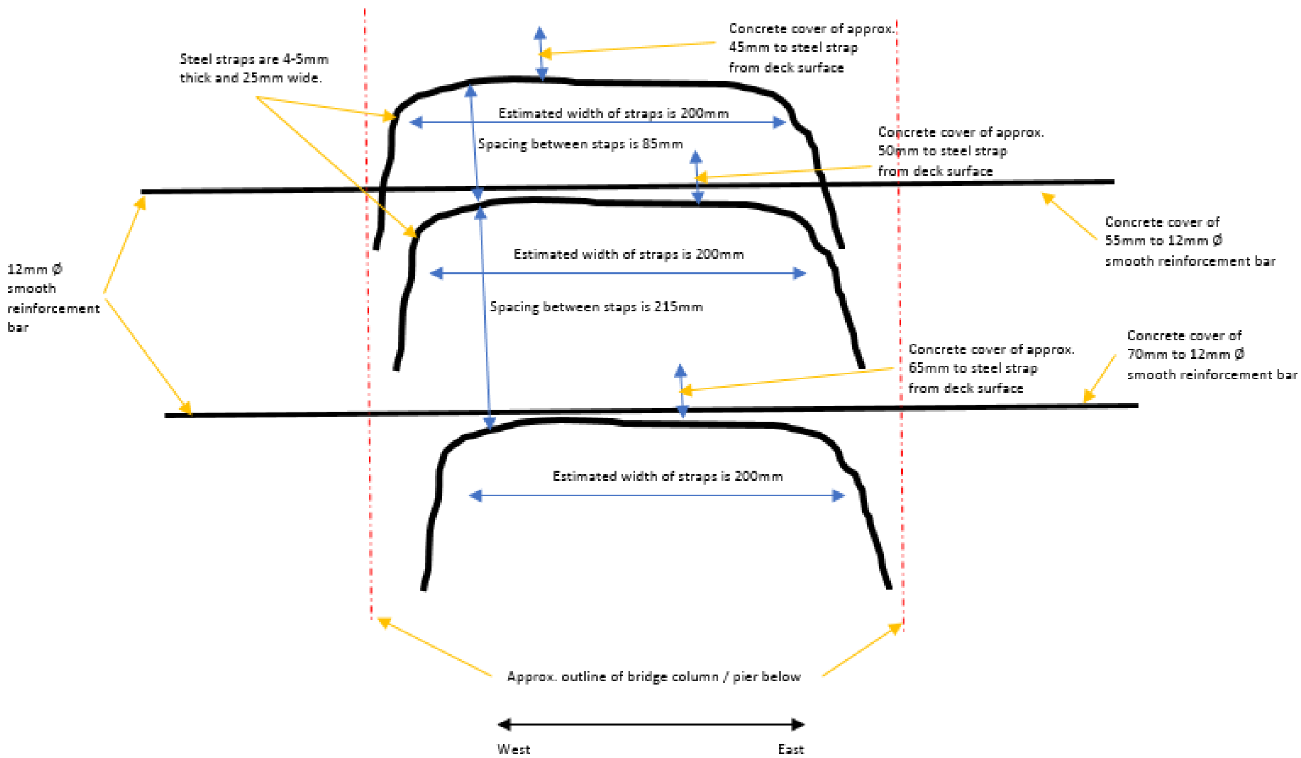
At this point, BHP completed a survey of the deck slab for the presence of reinforcement. At the point directly over the column, there was high concentrations of steel detected. This dissipated significantly once you moved of the bridge column. A breakout was completed to confirm the reinforcement within the slab and either side of the column.



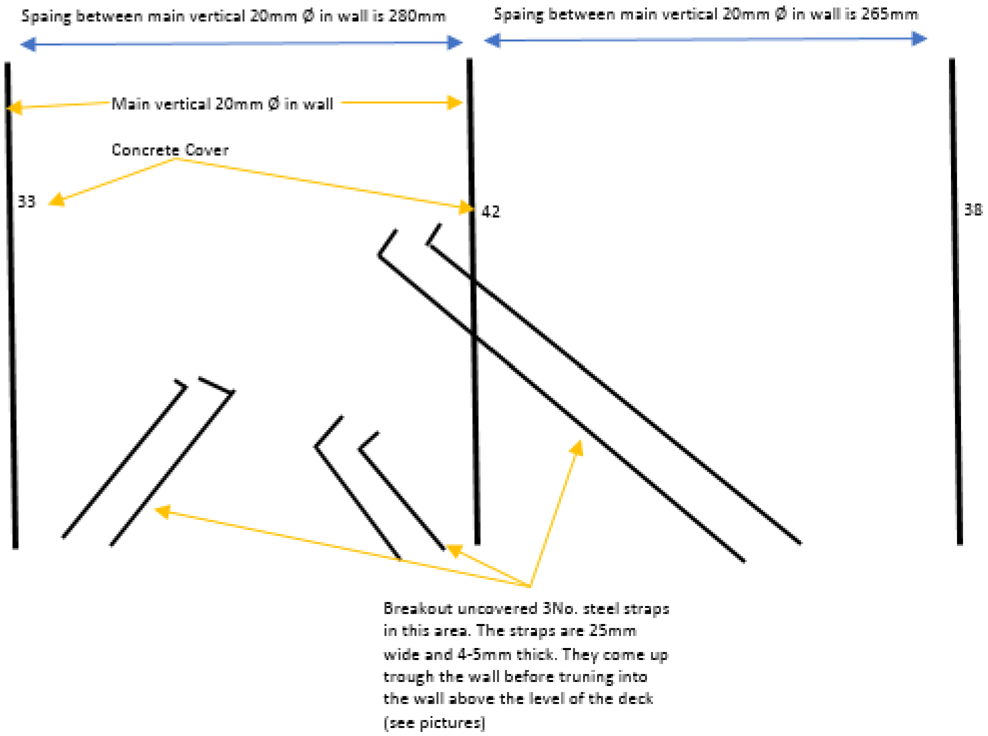
Side view of test areas



Plan view of test areas



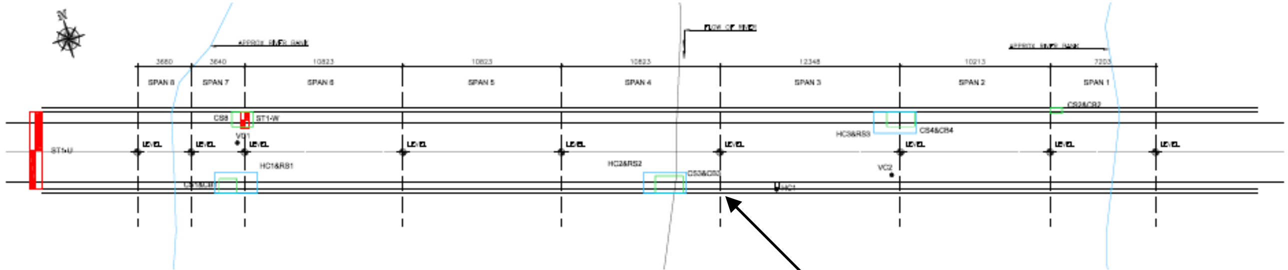
Breakout findings for CS4 & CB4 (deck slab)



Breakout findings for CS4 & CB4 (side wall)

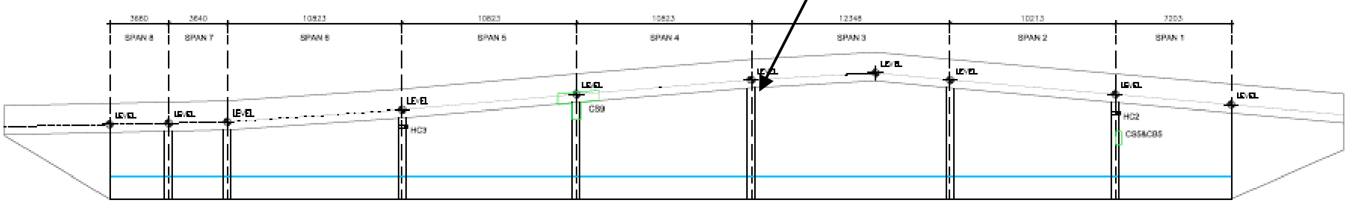
1.4 CS3 & CB3

As part of the survey work required at locations CS3 and CB3, BHP accessed the underside of the bridge using an underbridge unit supplied by Man Lift Ltd. Due to the steep incline and decline of the bridge arch, access to the underside of the bridge was limited to the slightly flat area in the centre point.



Plan view of bridge

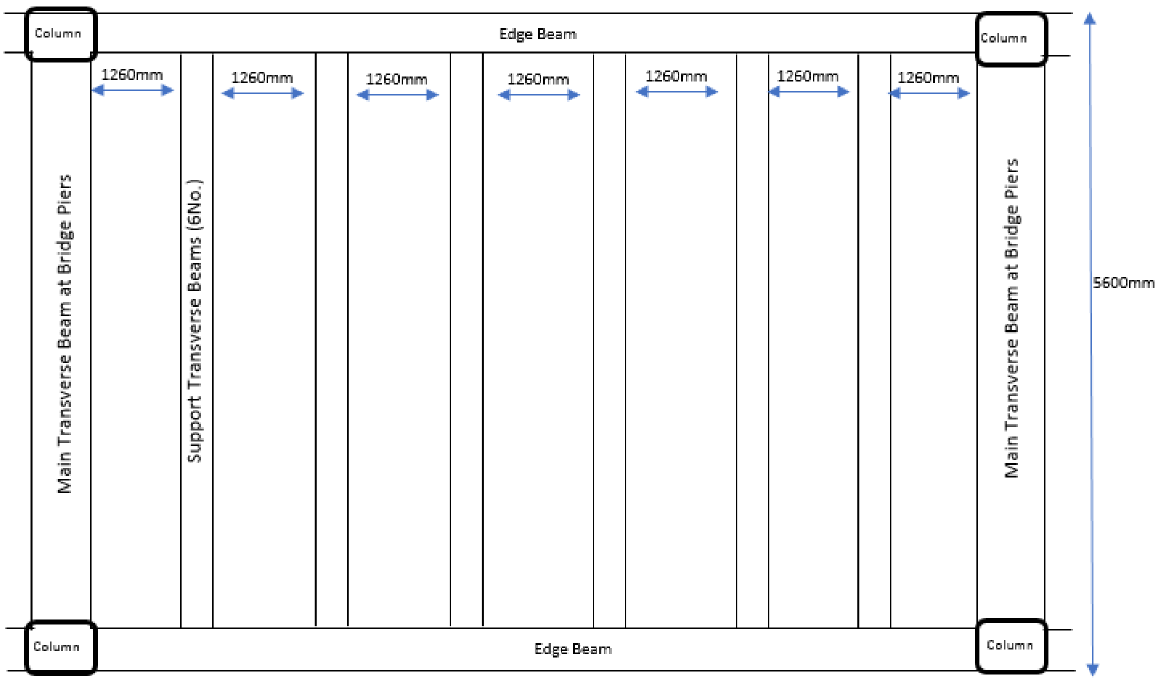
Slit Trench (SC3 & CB3)



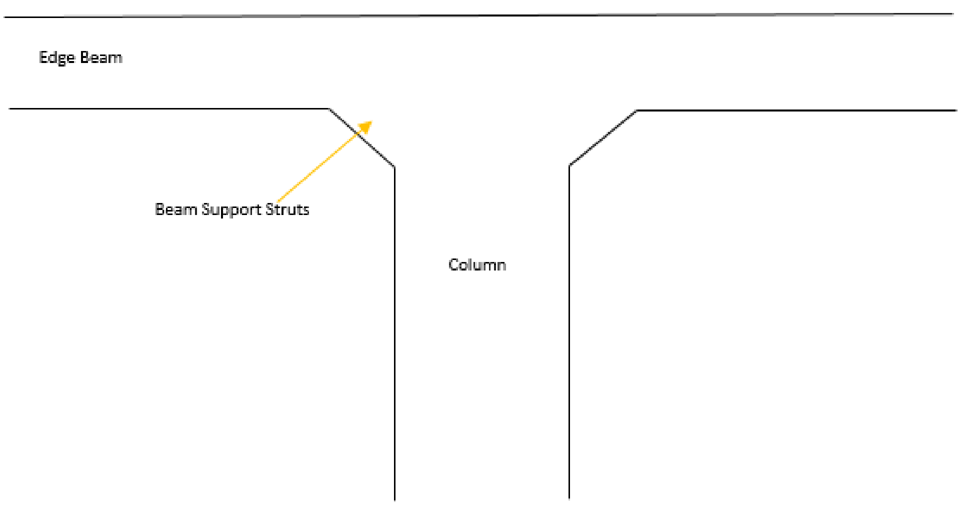
Side of elevation view of bridge

At this point, BHP completed a survey of the various reinforced concrete structural elements on the underside of the bridge. This included the following aspects:

- Bridge column
- Edge longitudinal beam
- Main transverse beam at pier location
- Diagonal support beam on pier
- Transverse beams in-between piers
- Deck Slab



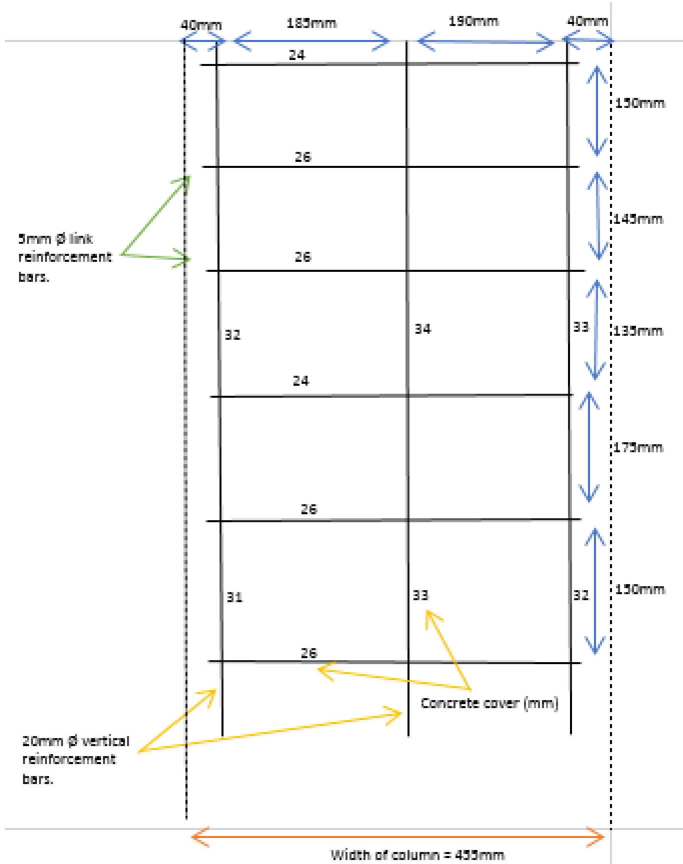
Plan view of bridge section



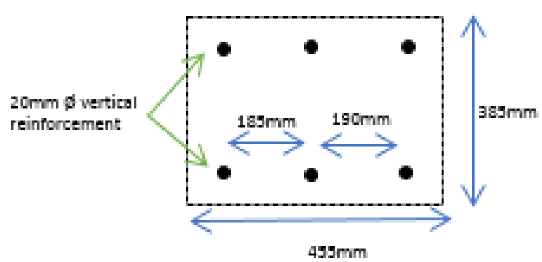
Side view of bridge pier / column section

1.4.1 Bridge Column

As part of the survey work required at location CS3 and CB3, BHP surveyed the bridge column. The face chosen for the survey was the eastern face. BHP also scanned the southern and northern faces to confirm dimensions, presence of reinforcement and spacing and cover of same. The sketches and pictures below confirm the findings of these surveys. In short, there is a pattern of 20mm diameter smooth reinforcement bars with 5mm links within the columns.



Breakout and cover scanning at CS3 & CB3 (column, east face)



Plan view of typical sketch of column following scanning and breakout confirmation

Breakout at CS3 & CB3 (column, east face)

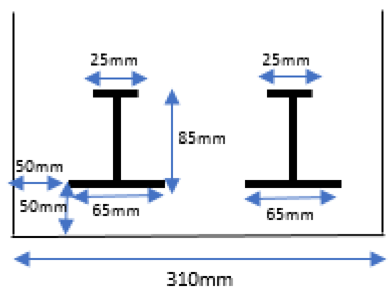
Breakout at CS3 & CB3 (column, east face – close up)

1.4.2 Bridge Edge Beam

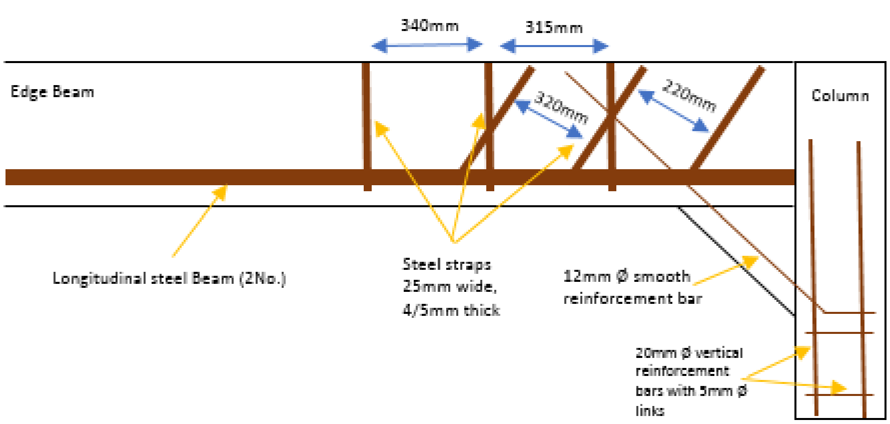
As part of the survey work required at location CS3 and CB3, BHP surveyed the edge beam. The face chosen for the survey was the southern face. BHP initially scanned the beam for the presence of steel reinforcement. The scanning identified significant amounts of steel within the base of the beam. A breakout confirmed the presence of steel beams running longitudinal to the road. There were 2 steel beams within the concrete edge beam. These beams measured approximately 65mm on the base of flange and 25mm on the top flange. The best estimate distance between the edge of the bottom flange and the web is 26-28mm. This would suggest a web thickness in the range 6-10mm. The estimated height of the beams was 85mm.

The beams are supported by steel straps. These straps are approximately 25mm wide and 4-5mm thick. There are two distinct types of straps on the edge beams – vertical and diagonal. There appears to be three diagonal straps either side of the bridge piers/columns. These are/were welded or attached to the centre point of the longitudinal steel beams. These appear to be the primary cause of the corrosion / concrete spalling. The cover appears to have been much lower to these than other steel elements within the concrete beams. In almost all locations, the concrete has spalled and the straps are in many cases full corroded and not providing any obvious support to the structure. The diagonal straps are spaced at approximately 250-350mm. The vertical straps are providing support to the longitudinal steel beams (in that they are still present in many cases and not widely corroded. There appears to be three of these straps running directly under the beams and continuing up into the top of the edge beam / deck slab – a breakout was carried out to chase these straps but it did not find an end point. It should be noted that the breakout of the bridge wall exposed steel straps at similar angles at CB4 and CS4. Perhaps these straps rung from top to bottom (at an angle) of the beams. The corroded sections of steel beams or straps was either on the soffit of the beams or inside side. There was no evidence of this on the exposed edges.

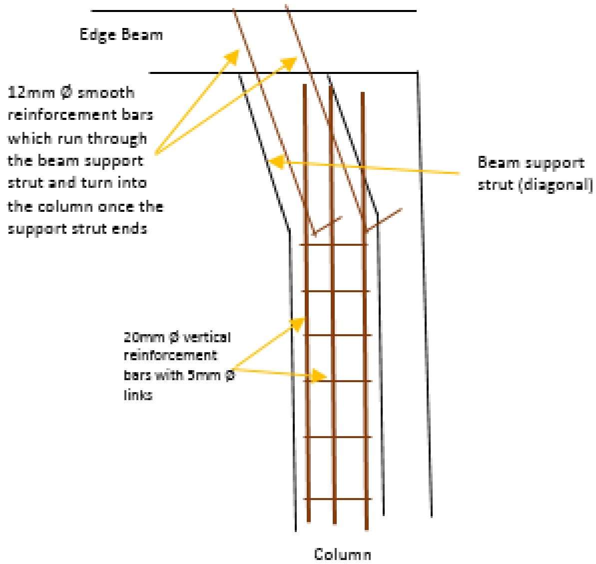
Each of the edge beams and transverse beams (at piers/columns) had diagonal support struts. These triangle shaped concrete supports were approximately 500-600mm in length on the exposed edge. The supports for the edge beams has 2 equally spaced 12mm Ø smooth reinforcement bars that continued from within the edge beam, through the strut and then turned 45° into the column. The breakout at CS3 CB3 found a 12mm Ø smooth bar within the column and stop before the concrete face. BHP assume this was a similar bar to these diagonal reinforcement bars except from the other side. The sketches below illustrate this assumption.



Sketch of make-up of edge beam (south side of bridge)



Sketch of make-up of edge beam (from inside looking out at edge beam on south side)

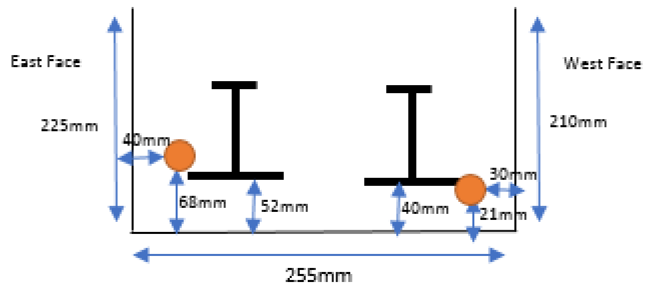


Sketch of make-up of support strut to edge beam from column

1.4.3 Transverse Beams

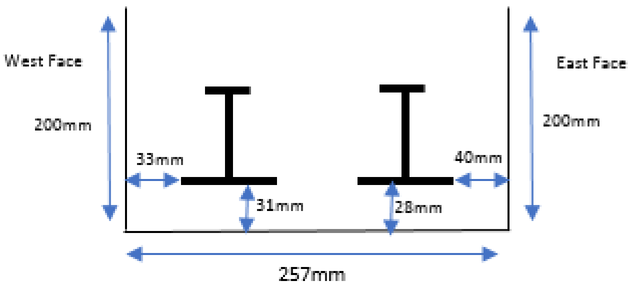
There are two forms of transverse beams on Hartley Bridge. There are transverse beams at pier/column locations and transverse beams spaced evenly throughout the span between piers/columns.

The make-up of the transverse beam at the pier/column locations is detailed below. There is a pattern of steel beams similar to those found in the edge beams (described in section 1.4.2). In addition to these, there are 2No. 20mm Ø smooth reinforcement bars running throughout the beam. These bars are set at alternate positions at the breakout location at CS3 and CB3. The sketch below confirms this positioning with the associated cover. It must be noted that the concrete at this location was extremely hollow with spalling likely to occur very soon. Great care was required to saw cut the dimensions of the breakout first as the kango vibration could have led to significant collapse of the transverse beam soffit/side concrete.



Sketch of make-up of transverse beam running from one side of the pier to another.

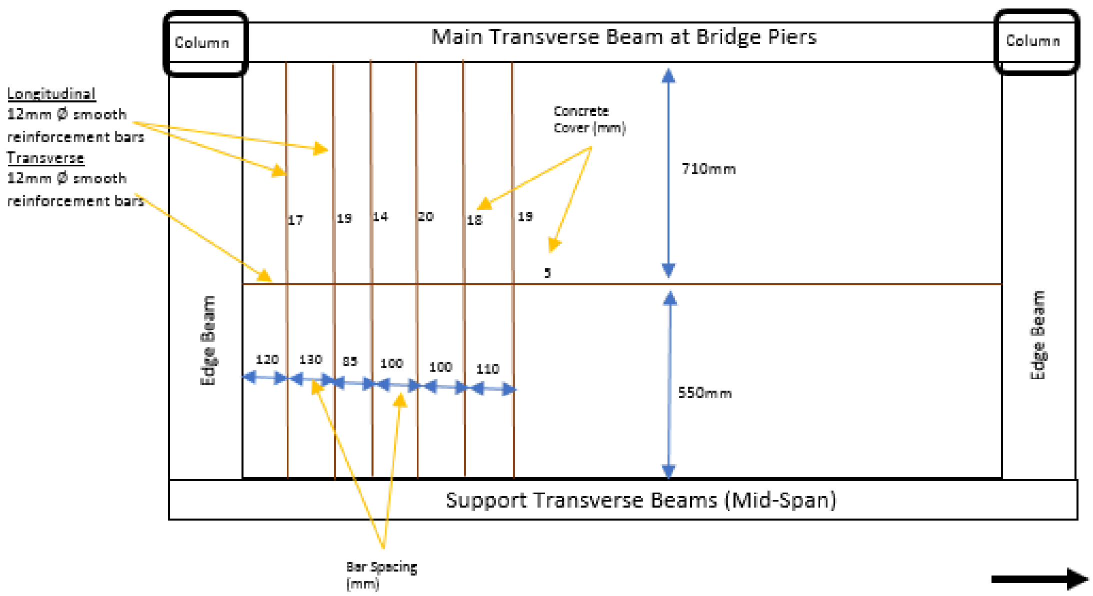
The transverse beams mid-span were similar to the ones at pier locations with the exception of no 20mm Ø steel reinforcement bars. The sketch below confirms the make-up of the first mid-span beam that is east of the pier at CS3 & CB3.



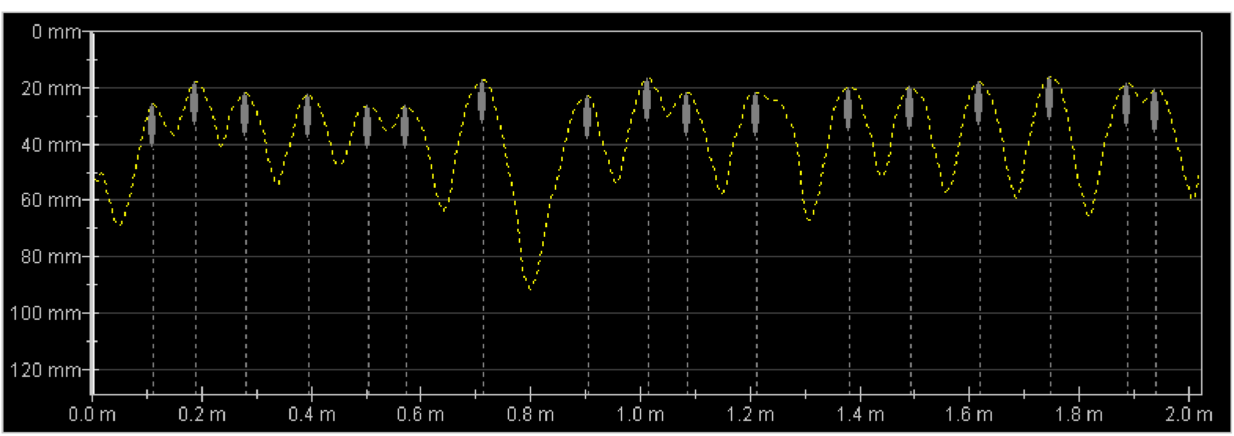
Sketch of make-up of transverse beam in the mid span of the bridge

1.4.4 Bridge Deck Soffit

As part of the survey work required at location CS3 and CB3, BHP surveyed the bridge deck soffit. The survey took place on the section of deck slab that was east of the pier location at CS3 and CB3. In short, there are a series of 12mm Ø smooth reinforcement bars running longitudinal to the road. These bars are spaced at approximately 85-150mm and have concrete cover of approximately 20mm. There are many locations where the reinforcement bars are demonstrating corrosion that leads to concrete spalling and stained surfaces. In each span there is also one 12mm Ø smooth reinforcement bar running transverse to the road. This bar is placed below the longitudinal bars. Its location varies from span to span but tends to be roughly in the middle. Due to it being placed below the other directional bars, the cover is extremely low. At this survey location, where concrete covered the bar, it was approximately 5-6mm in depth. As a result and throughout the bridge, these bars are exposed due to concrete spalling and appear to be highly corroded.



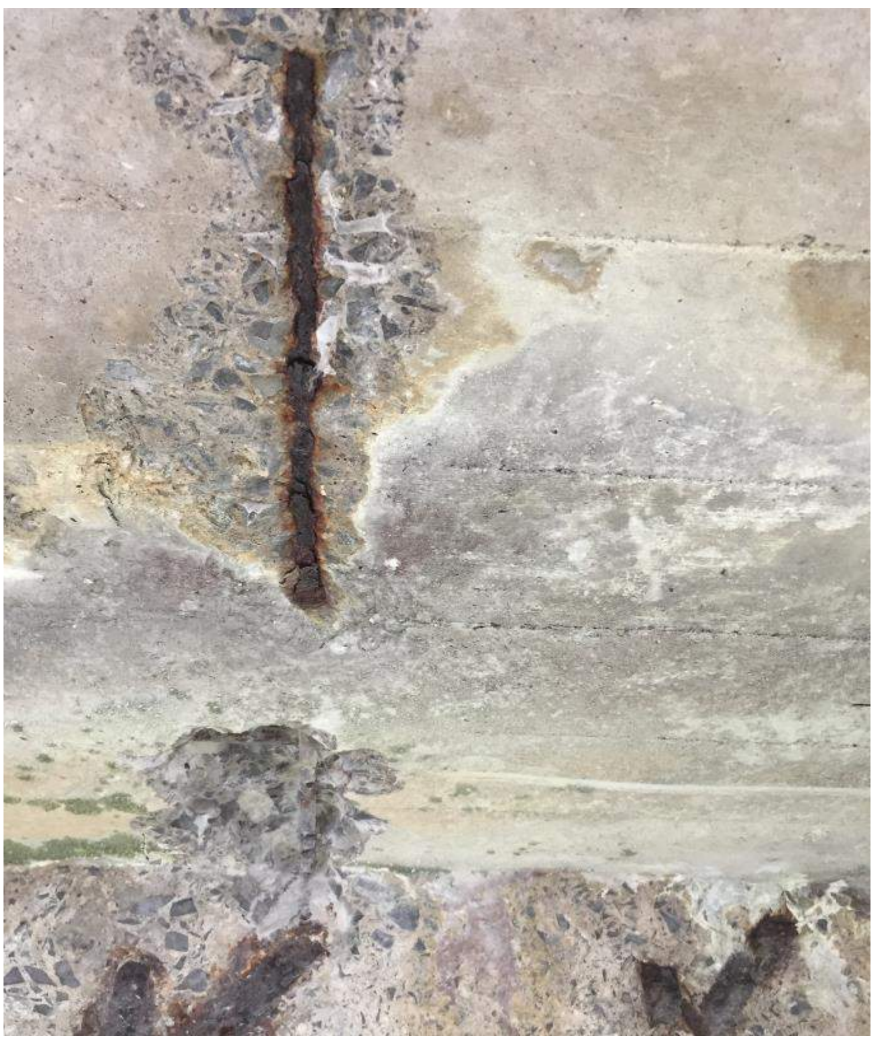
Sketch of make-up of deck slab soffit



Scanning of deck slab soffit from south to north in section without transverse reinforcement

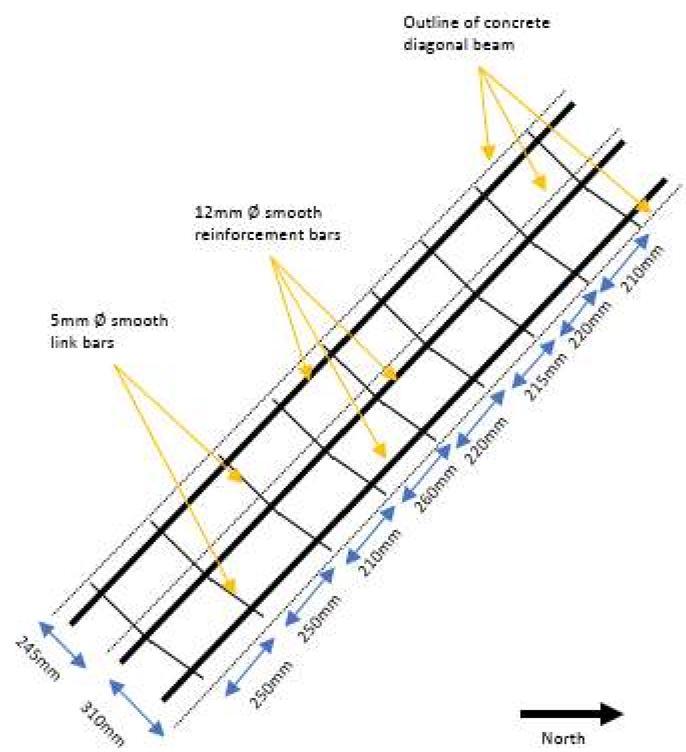
No. of Readings	17
Median (mm)	20.7
Mean (mm)	20.7
Standard Deviation (mm)	3.2
Lowest (mm)	16
Highest (mm)	26

Statistics of cover for longitudinal reinforcement bars in deck slab soffit



1.4.5 Bridge Diagonal Support Beam

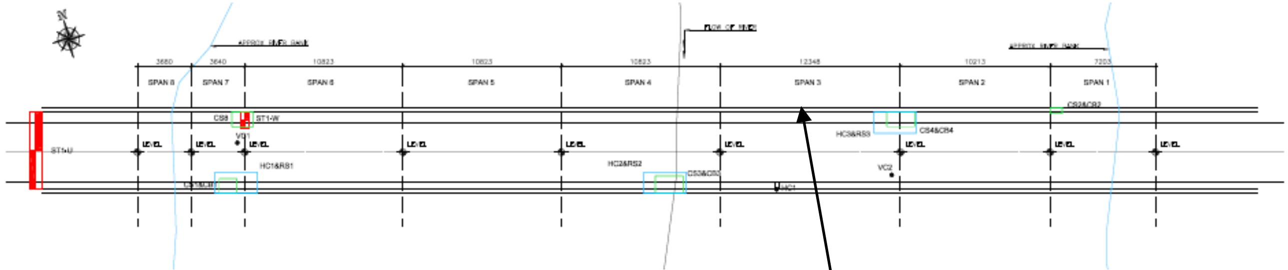
As part of the survey work required at location CS3 and CB3, BHP surveyed the diagonal support beam that runs from the bottom of the south side column to the top of the column on the north side. This diagonal is made up of 4No. 12mm Ø smooth reinforcement bars that are linked with 5mm Ø link bars. The frame of reinforcement is quite uniform throughout the beam surveyed. There is concrete cover to all four bars in the range of 37-44mm at select locations. The links are placed tightly around these main bars so cover is approximately 32-39mm. The links are spaced at approximately 220mm.



Sketch of make-up of diagonal support beam

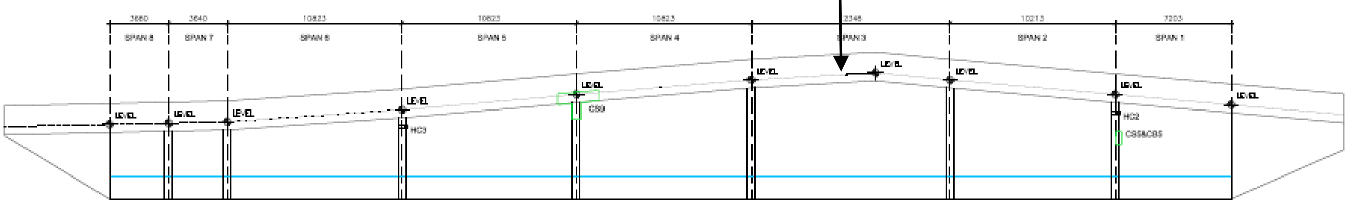
1.5 CS3 & CB3 (Top of Bridge Side Wall)

As part of the survey work required close to CS3 and CB3, BHP undertook a breakout and scanning to the top of the wall that runs along both sides of the bridge.



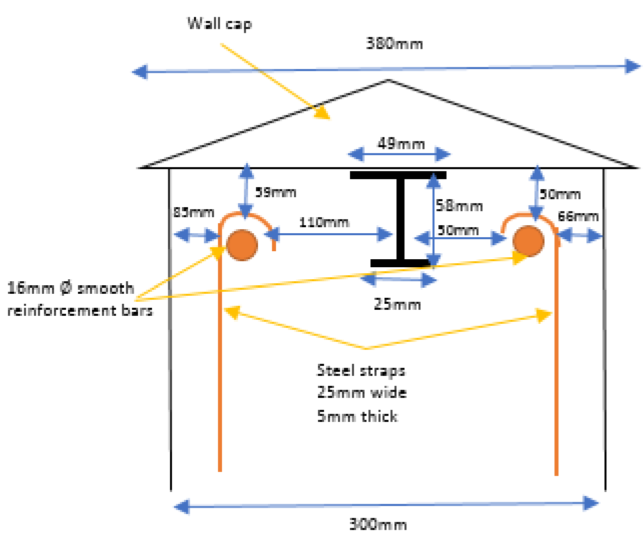
Plan view of bridge

Breakout to side wall



Side of elevation view of bridge

From this breakout, BHP identified a distinctive pattern of embedded steel within the wall. The sketch below confirms what was identified.



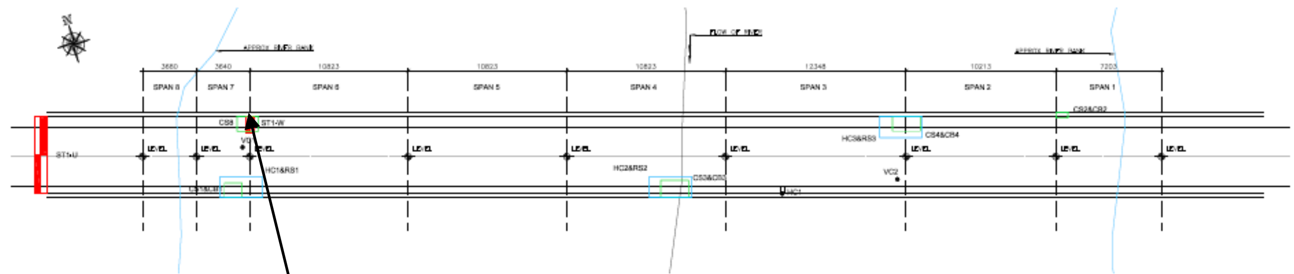
Sketch of make-up of bridge wing wall

Breakout of top of wall (please note beam was cut for tensile test)

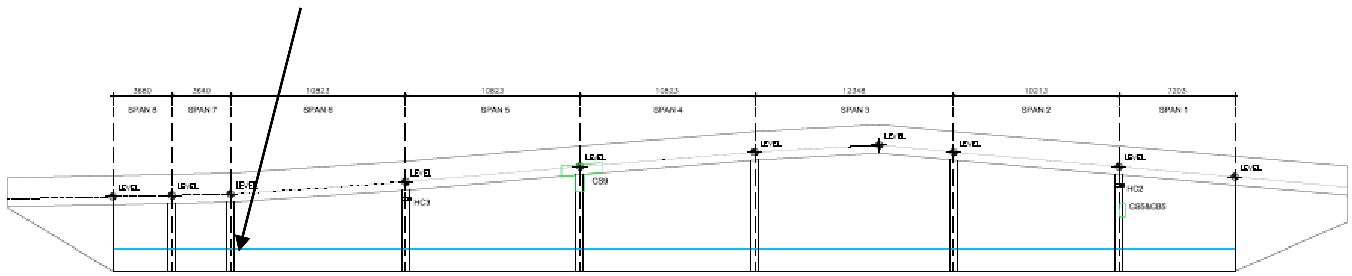
1.6 Survey work of column on west side of bridge

In addition to the survey work on the various elements on the centre point of Hartley Bridge, BHP completed a series of similar surveys on the west side of the bridge. The survey work was completed from scaffolds set up on the bank of the river.

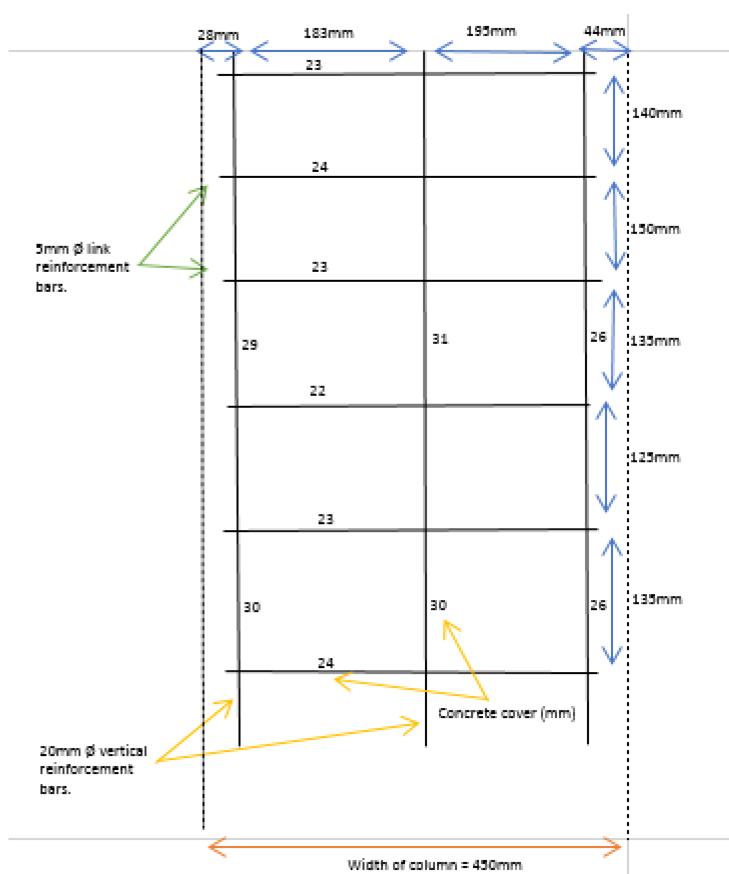
The first survey work was completed on the column on the north side of the bridge. At this point was the intersection of the main bridge section with the support structure to the west of it. There was two columns side by side (see photographs). The survey would was completed on the main bridge structure.



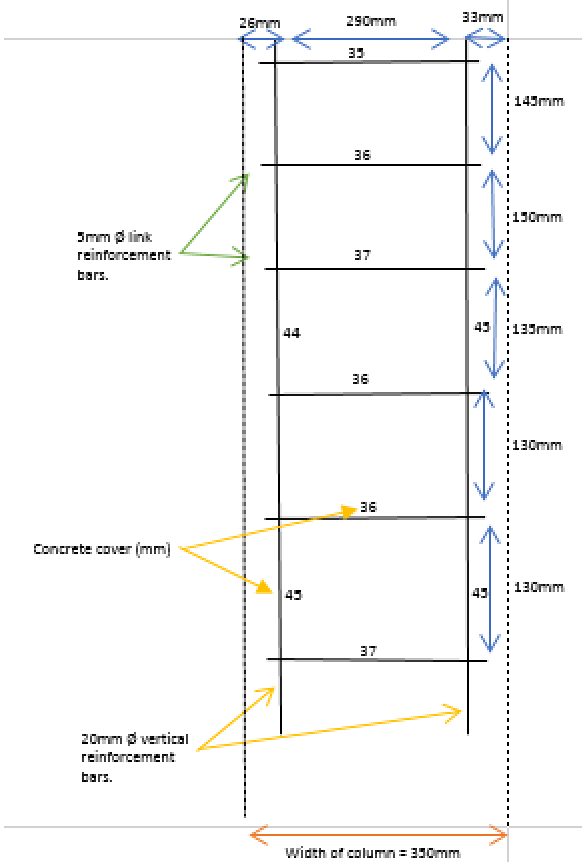
Plan view of bridge



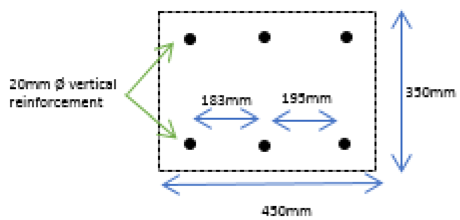
Side of elevation view of bridge



Sketch of make-up of the east side of the column

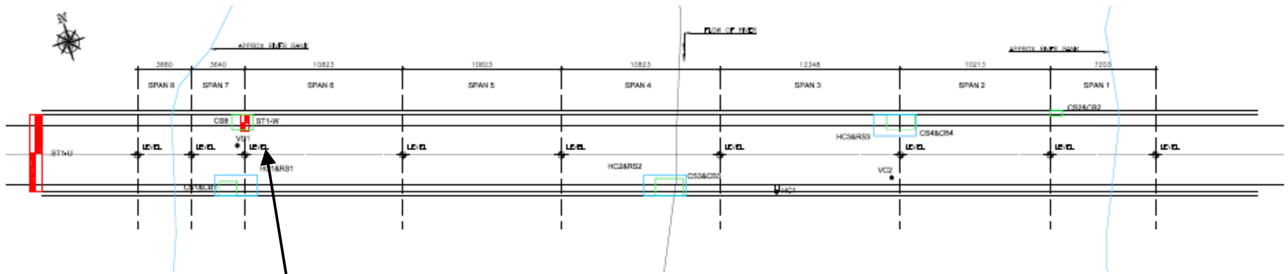


Sketch of make-up of the north side of the column



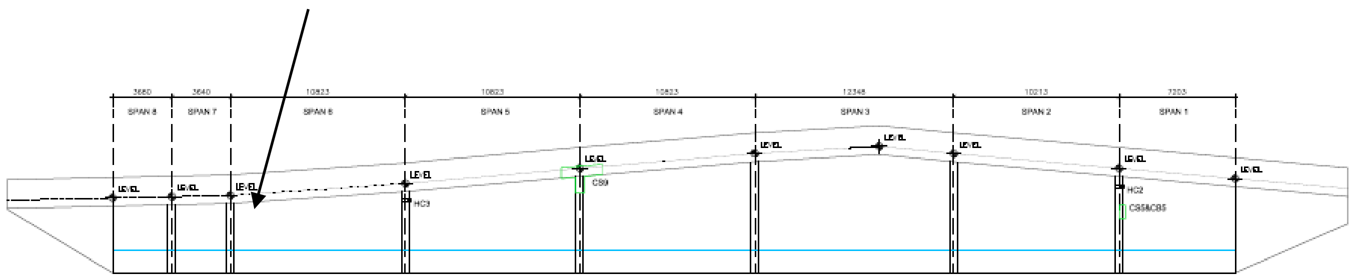
Plan view of reinforcement arrangement in column

The results of the column scanning at this location backed up those found in the centre of the bridge. Similar to many locations throughout the bridge, much of the reinforcement was visible. This was due to concrete spalling. At each location of spalling, the reinforcement clearly demonstrated that corrosion was taking place. To confirm the reinforcement within the deck slab, we undertook two further scans for transverse and longitudinal bars. The transverse reinforcement was clearly visible again due to spalling along its base. The longitudinal reinforcement was identified and logged as follows:

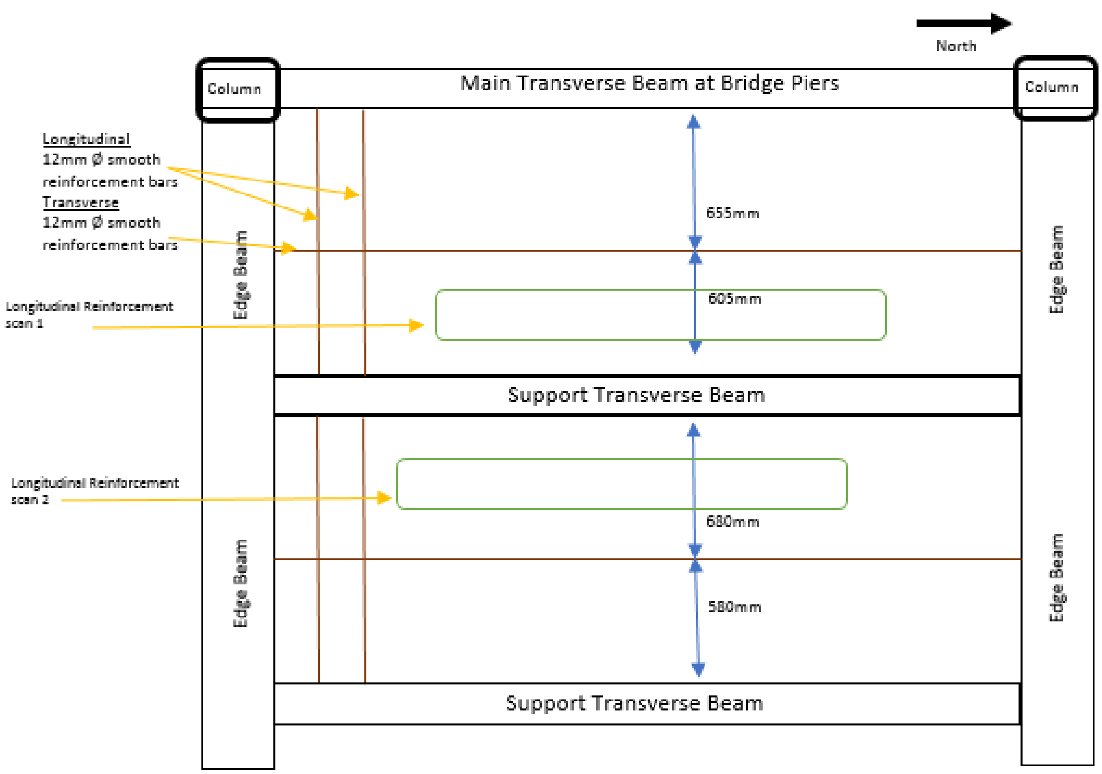


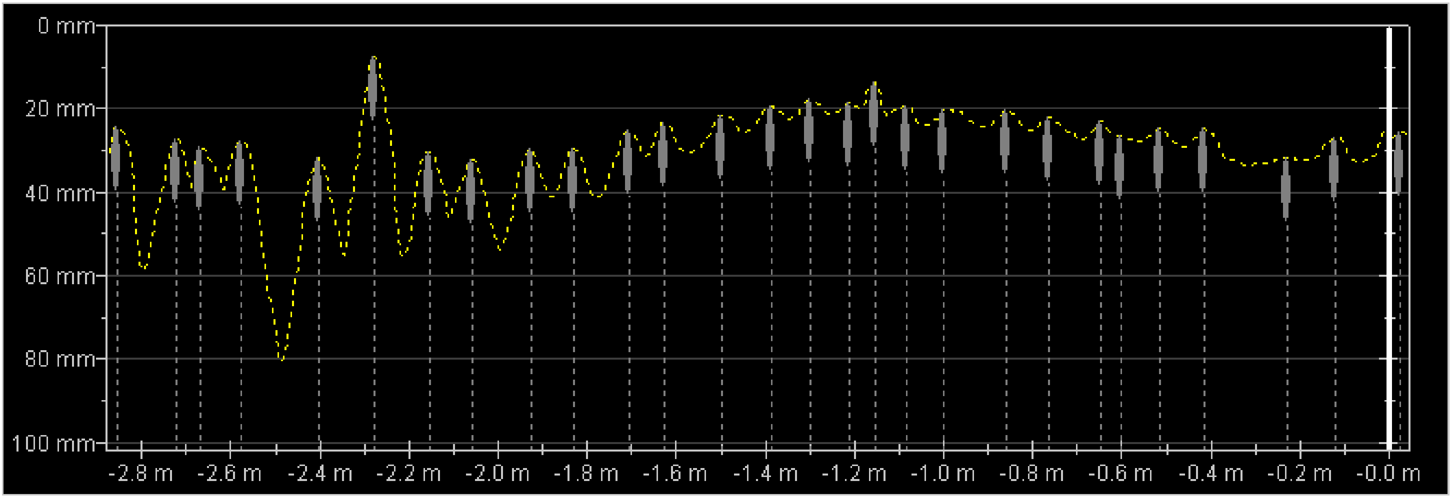
Plan view of bridge

Scanning & breakout of deck slab reinforcement

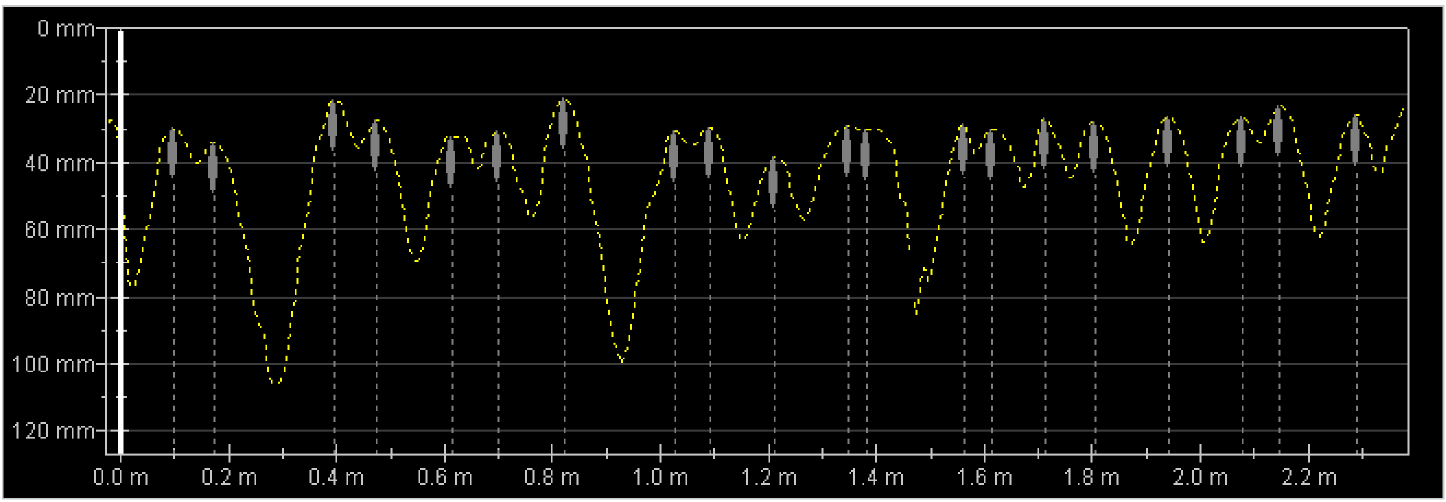


Side of elevation view of bridge





Longitudinal Reinforcement Scan 1



Longitudinal Reinforcement Scan 2

Conducting of Scan 1

Breakout to confirm transverse reinforcement

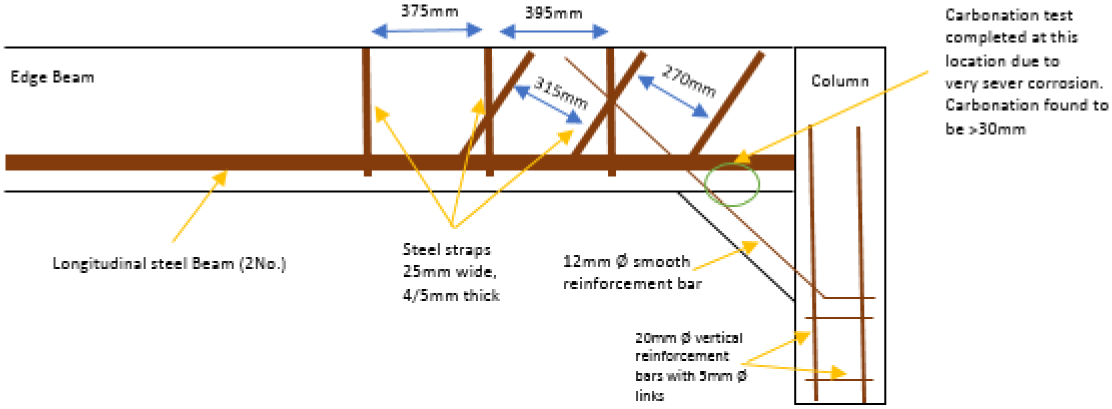
Close up of transverse reinforcement

Evidence of honeycombed concrete surrounding corrode longitudinal reinforcement bar in deck

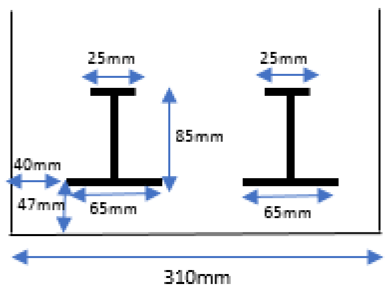
Evidence of corroded reinforcement bar in the deck slab soffit which has led to spalled concrete

The final survey work was completed on the edge beam to confirm findings at the centre of the bridge and to complete a breakout of the transverse beam as it connects with the edge beam.

The findings of the edge beam were consistent with the first survey in the mid span of the bridge. There is a mixture of longitudinal beams (2No.) in the edge concrete beam with diagonal and vertical support straps around the columns. The sketches below confirm this finding.



Sketch of make-up of edge beam (from inside looking out at edge beam on south side)



Sketch of make-up of edge beam (south side of bridge)

At this location there was adequate space to complete a comprehensive breakout of the transverse support beam (in between piers). The photographs confirm the transverse beam continues into the edge beam and rests on top of the main longitudinal steel beam.

Due to widespread corrosion of beams at this location, BHP chiseled away some of the corroded steel on beams. The thickness of the edge flange did not fall below 9-10mm at these locations. The edge thickness of the flange was measured to be 12mm at a non-corroded area.

Authorised by: Date Issued: 22nd July 2017

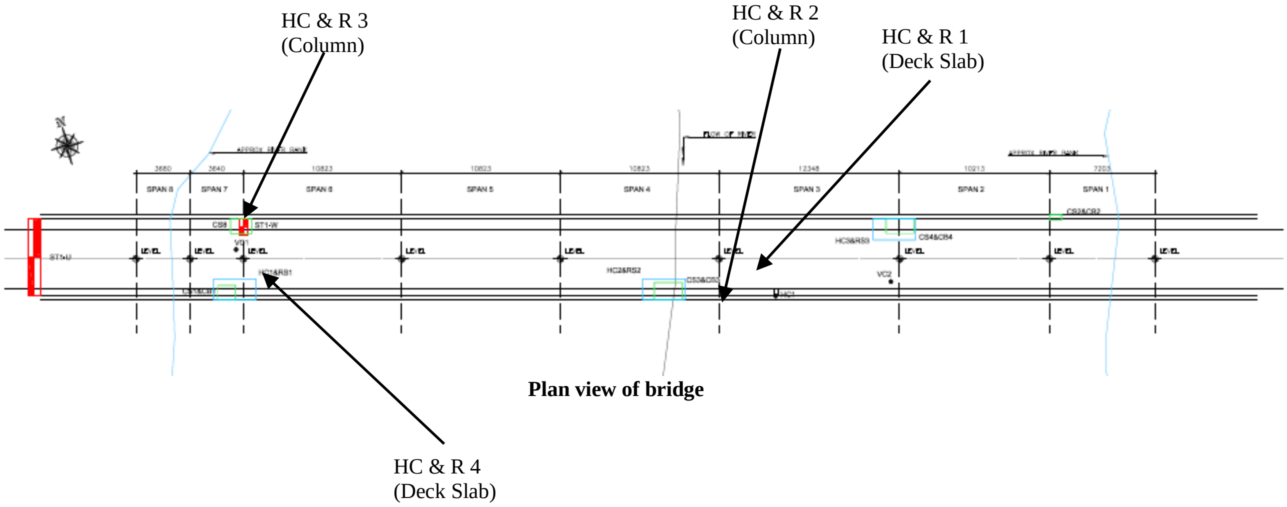
James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories Ltd.

Test results relate only to this item. This test report shall not be duplicated except in full and with the permission of the test laboratory

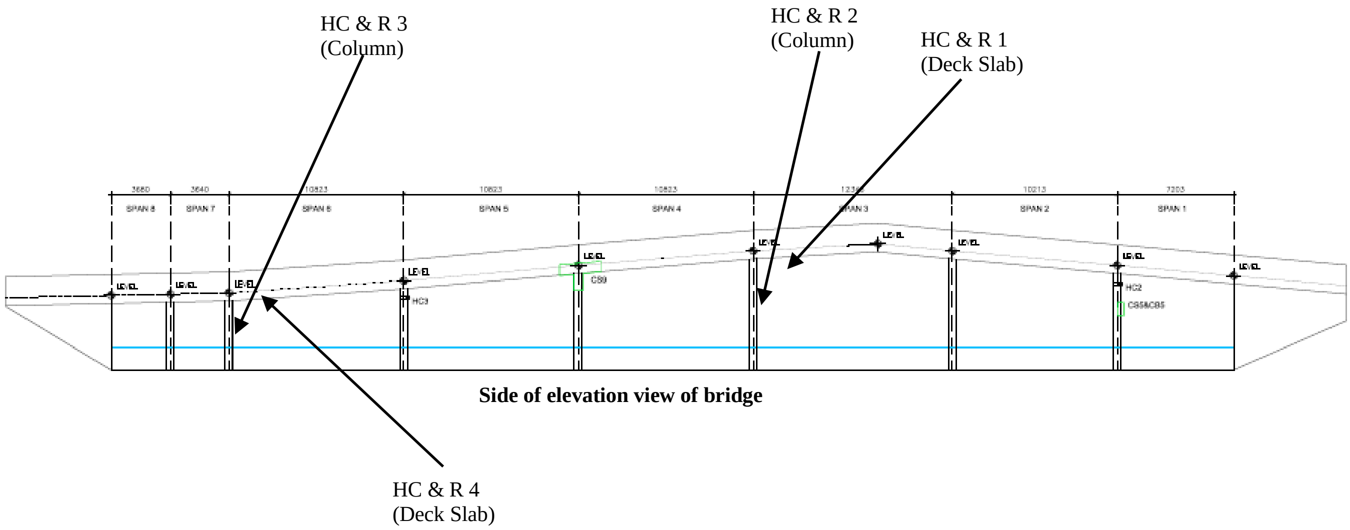
Appendix F

Half Cell & Resistivity Test Reports

Half Cell & Resistivity Test Locations



Plan view of bridge



Side of elevation view of bridge

Form No.: BHP/MTI/0170 1.1 27/09/06

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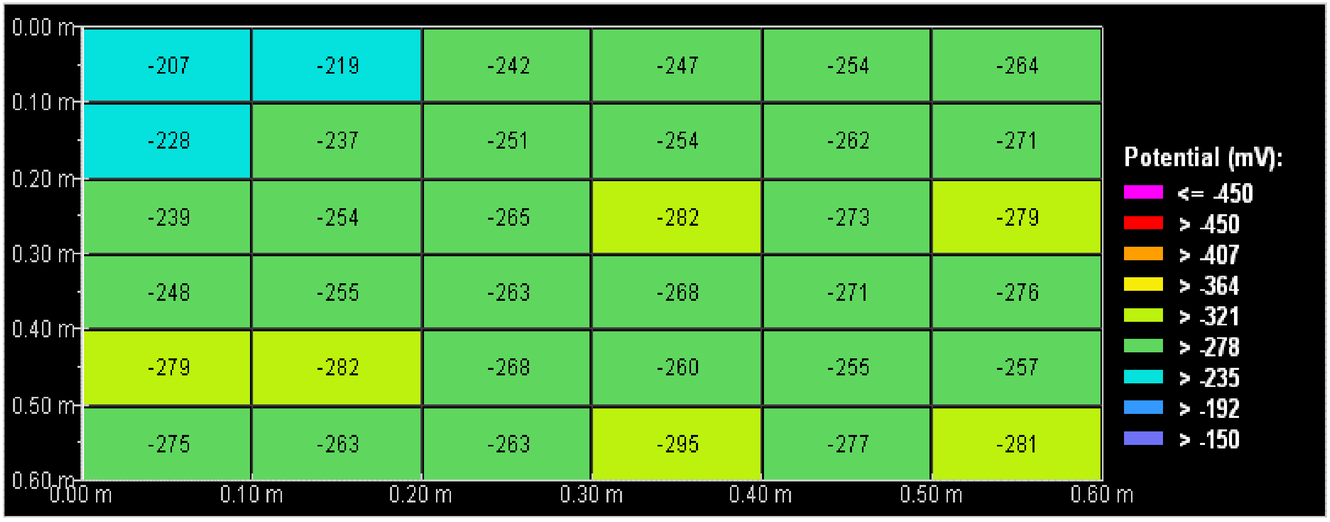
Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/137-1
		Order No:	Not Supplied
		Date Visited:	19/04/2017
		Date Tested:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Half Cell Testing
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING

Sample Reference	:	17/05/137-1
Structural Element	:	Deck slab (CS4 & CB4)
Test Number	:	Half Cell Test 1
Reinforcement Condition	:	Mild surface corrosion



Remarks:

This test was performed using a Copper-Copper Sulphate Electrode.

The range of values is -207 to -295 with a mean value of -260 and a standard deviation of 18.3.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017

TEST REPORT

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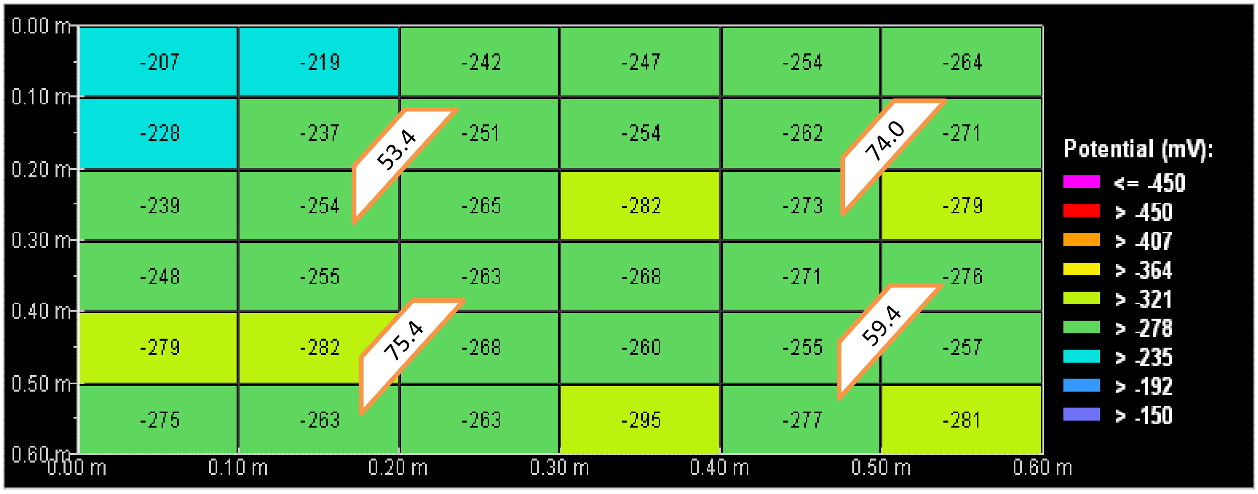
Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/137-1
		Order No:	Not Supplied
		Date Visited:	19/04/2017
		Date Tested:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Resistivity
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

RESISTIVITY MEASUREMENTS ON CONCRETE

Sample Reference	:	17/05/137-1
Structural Element	:	Deck slab (CS4 & CB4)
Test Number	:	Half Cell Test 1
Equipment Used	:	Proceq Resipod
Serial Number	:	RP01-005-0041
Measurement Mode	:	Surface
Contact Spacing	:	50mm
Specimen Shape	:	Rough surface
Minimum Measurement	:	53.4 kΩcm
Maximum Measurement	:	75.4 kΩcm
Mean Value	:	65.6 kΩcm



Remarks:

Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.

A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	-	Negligible risk of corrosion
When 50 to 100 kΩcm	-	Low risk of corrosion
When 10 to 50 kΩcm	-	Moderate risk of corrosion
When ≤ 10 kΩcm	-	High risk of corrosion

Based on the resistivity measurements for this location, there is a low risk of corrosion.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017

Form No.: BHP/MTI/0170 1.1 27/09/06

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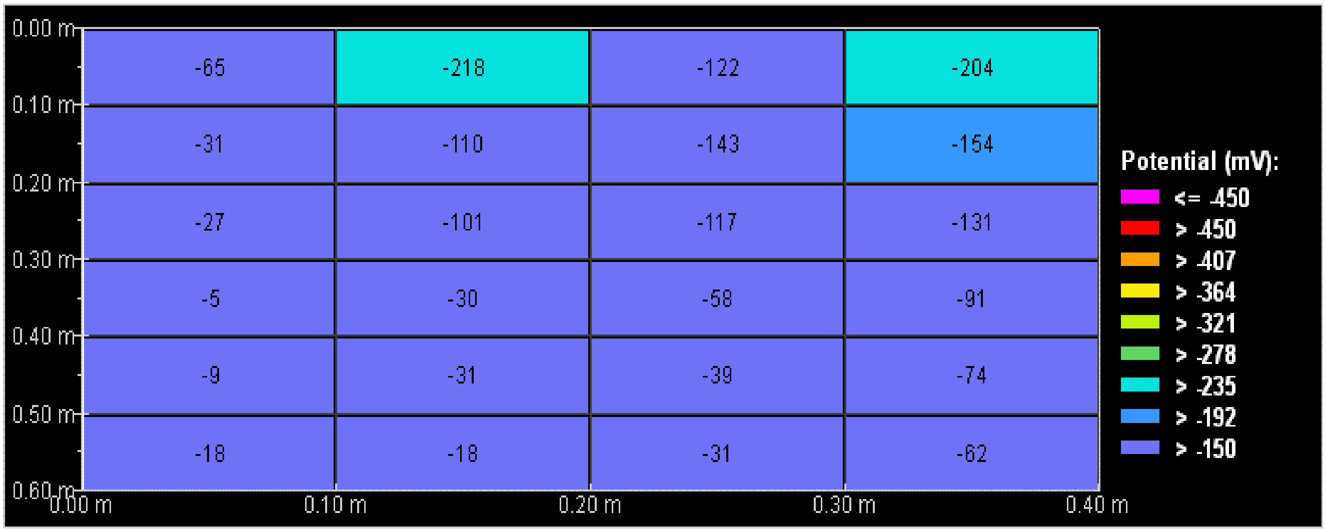
Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/137-2
		Order No:	Not Supplied
		Date Visited:	19/04/2017
		Date Tested:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Half Cell Testing
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING

Sample Reference	:	17/05/137-2
Structural Element	:	Column, east face (CS3 & CB3)
Test Number	:	Half Cell Test 2
Reinforcement Condition	:	No to mild surface corrosion



Remarks:

This test was performed using a Copper-Copper Sulphate Electrode.

The range of values is -5 to -218 with a mean value of -78.7 and a standard deviation of 59.4.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017

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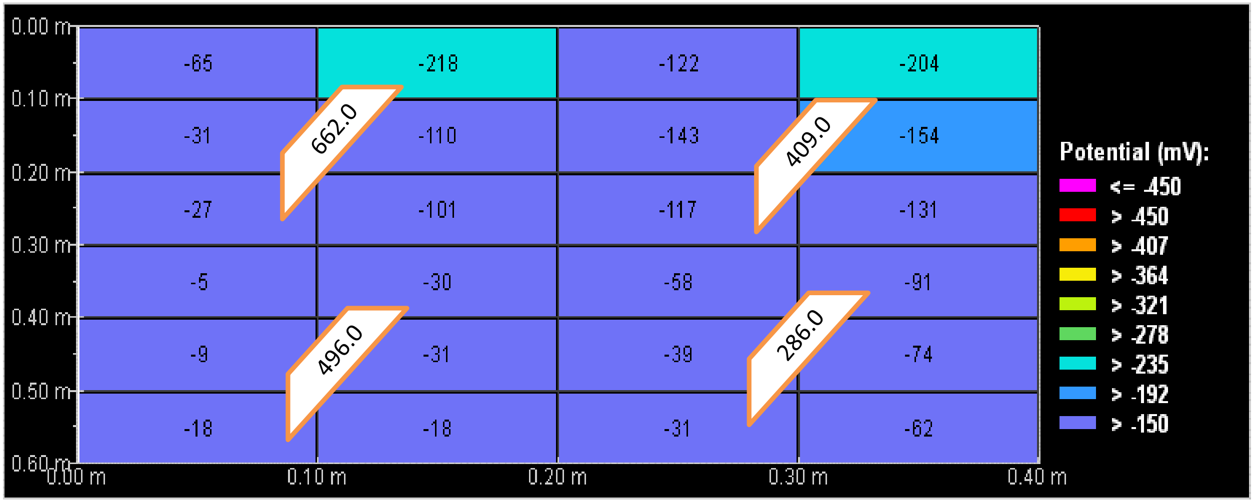
Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.:**	17/05/137-2
		Order No:	Not Supplied
		Date Visited:	19/04/2017
		Date Tested:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item :**	Concrete Resistivity

Client Reference: Hartley Bridge, Carrick-On-Shannon, Co. Leitrim

RESISTIVITY MEASUREMENTS ON CONCRETE

Sample Reference	:	17/05/137-2
Structural Element	:	Column, east face (CS3 & CB3)
Test Number	:	Half Cell Test 2
Equipment Used	:	Proceq Resipod
Serial Number	:	RP01-005-0041
Measurement Mode	:	Surface
Contact Spacing	:	50mm
Specimen Shape	:	Rough surface
Minimum Measurement	:	286.0 kΩcm
Maximum Measurement	:	662.0 kΩcm
Mean Value	:	463.3 kΩcm



Remarks:

Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.

A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	-	Negligible risk of corrosion
When 50 to 100 kΩcm	-	Low risk of corrosion
When 10 to 50 kΩcm	-	Moderate risk of corrosion
When ≤ 10 kΩcm	-	High risk of corrosion

Based on the resistivity measurements for this location, there is a negligible risk of corrosion.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017

Form No.: BHP/MTI/0170 1.1 27/09/06

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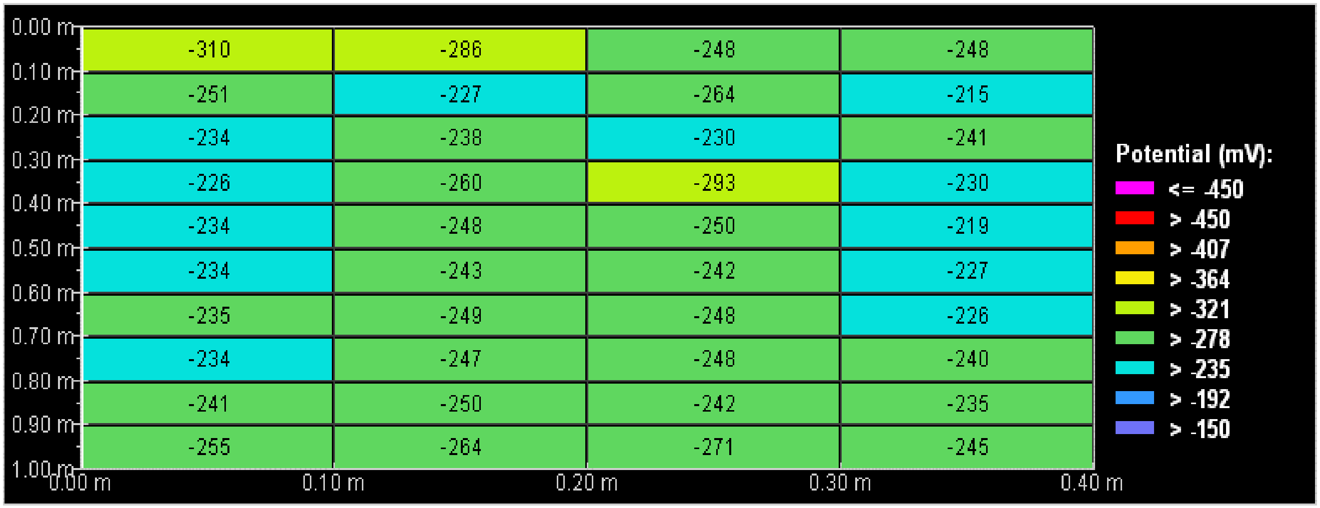
Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**:	17/05/137-3
		Order No:	Not Supplied
		Date Visited:	19/04/2017
		Date Tested:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Half Cell Testing
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING

Sample Reference	:	17/05/137-3
Structural Element	:	Column, east face (over land)
Test Number	:	Half Cell Test 3
Reinforcement Condition	:	Mild surface corrosion



Remarks:

This test was performed using a Copper-Copper Sulphate Electrode.

The range of values is -215 to -310 with a mean value of -245.7 and a standard deviation of 18.9.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

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	Áras an Chontae	**Order No**:	Not Supplied
	Carrick on Shannon	**Date Visited**:	19/04/2017
	Co. Leitrim	**Date Tested**:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Resistivity
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

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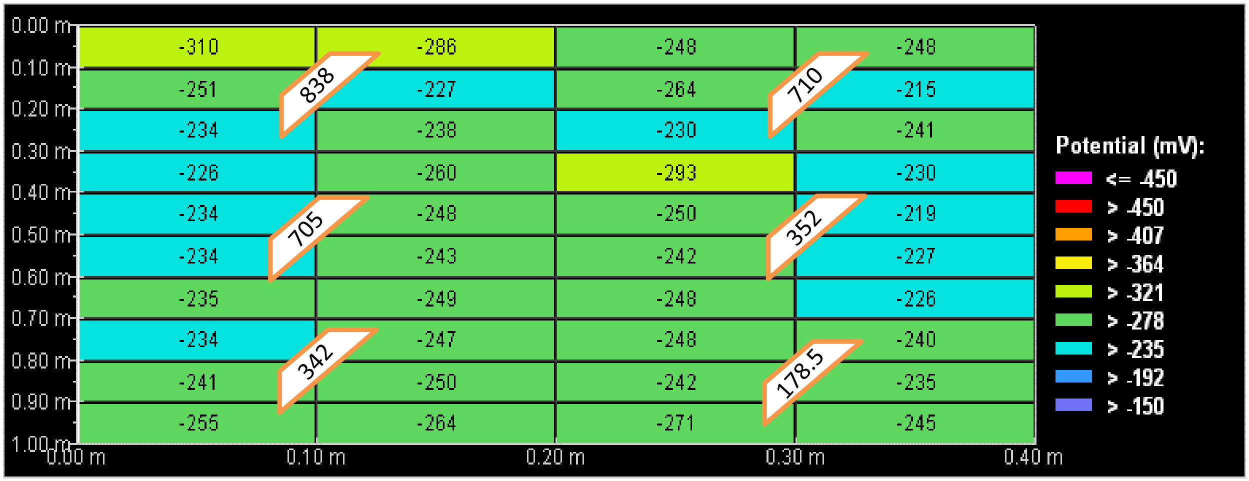
RESISTIVITY MEASUREMENTS ON CONCRETE

Sample Reference	:	17/05/137-3
Structural Element	:	Column, east face (Over Land)
Test Number	:	Half Cell Test 3
Equipment Used	:	Proceq Resipod
Serial Number	:	RP01-005-0041
Measurement Mode	:	Surface
Contact Spacing	:	50mm
Specimen Shape	:	Rough surface
Minimum Measurement	:	178.0 kΩcm
Maximum Measurement	:	838.0 kΩcm
Mean Value	:	520.9 kΩcm



Remarks:

Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.

A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	-	Negligible risk of corrosion
When 50 to 100 kΩcm	-	Low risk of corrosion
When 10 to 50 kΩcm	-	Moderate risk of corrosion
When ≤ 10 kΩcm	-	High risk of corrosion

Based on the resistivity measurements for this location, there is a negligible risk of corrosion.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017

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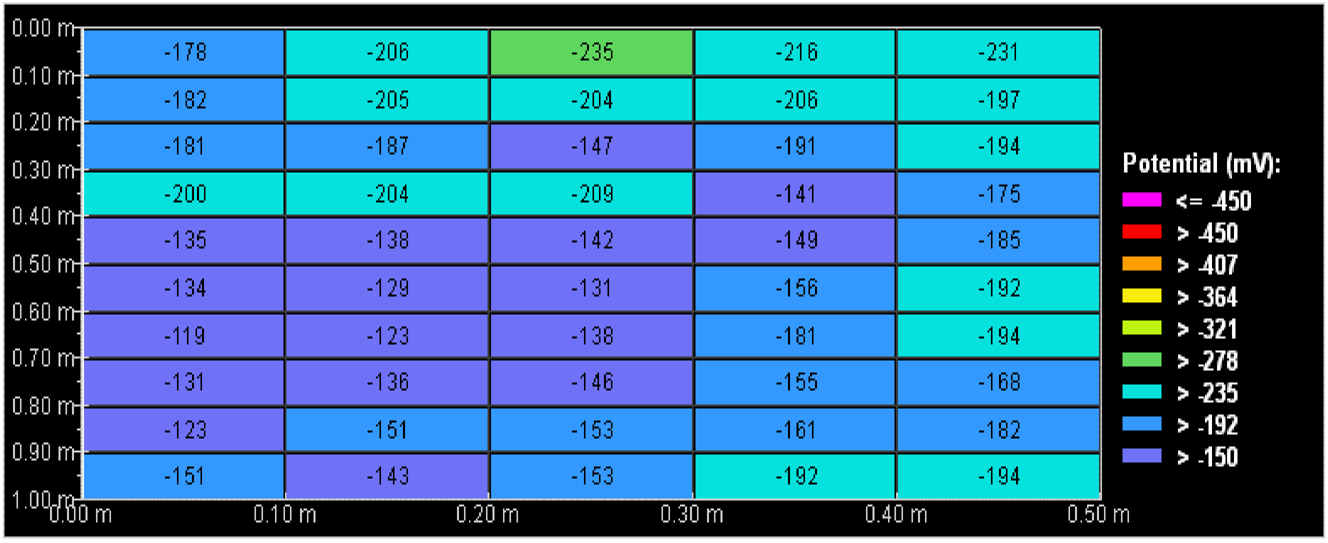
Client:	Leitrim County Council Áras an Chontae Carrick on Shannon Co. Leitrim	**BHP Ref. No.**: **Order No**: **Date Visited**: **Date Tested**: **Test Specification**:	17/05/137-4 Not Supplied 19/04/2017 19/04/2017 Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Half Cell Testing
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING

Sample Reference	:	17/05/137-4
Structural Element	:	Deck soffit (over land)
Test Number	:	Half Cell Test 4
Reinforcement Condition	:	Mild surface corrosion



Remarks:

This test was performed using a Copper-Copper Sulphate Electrode.

The range of values is -119 to -235 with a mean value of -169.5 and a standard deviation of 30.6.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017

Test results relate to the samples, as supplied . This test report shall not be duplicated in full without the permission of the test laboratory.

Sampling details where supplied are held on file.

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Client:	Leitrim County Council	**BHP Ref. No.**:	17/05/137-4
	Áras an Chontae	**Order No**:	Not Supplied
	Carrick on Shannon	**Date Visited**:	19/04/2017
	Co. Leitrim	**Date Tested**:	19/04/2017
		Test Specification:	Client Spec.
F.T.A.O.:	Mr. Michael Gallagher	**Item** :	Concrete Resistivity
Client Reference:	Hartley Bridge, Carrick-On-Shannon, Co. Leitrim		

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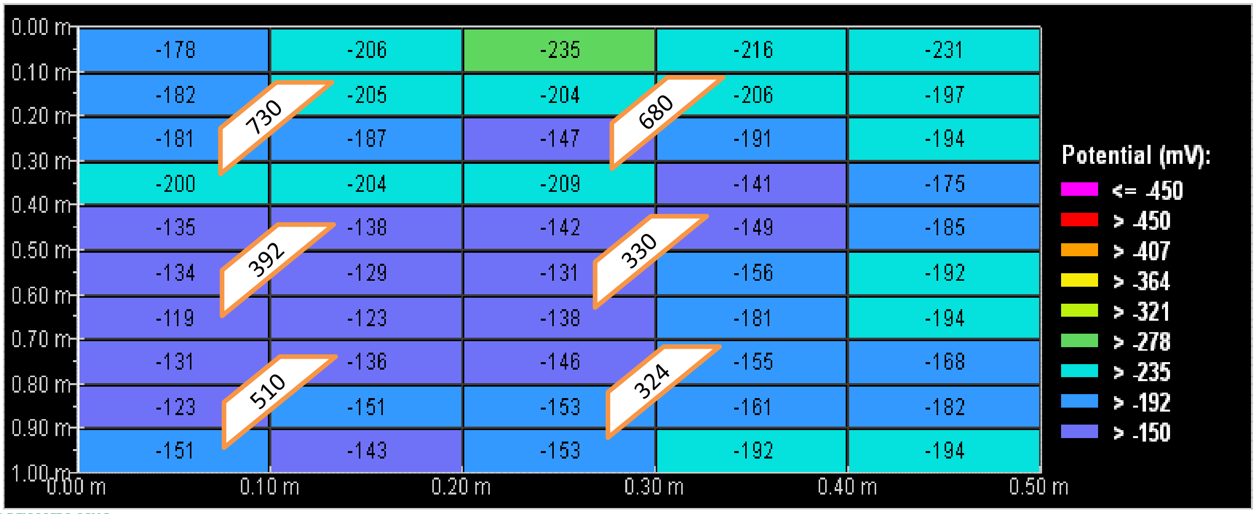
RESISTIVITY MEASUREMENTS ON CONCRETE

Sample Reference	:	17/05/137-4
Structural Element	:	Deck Slab Soffit (Over Land)
Test Number	:	Half Cell Test 4
Equipment Used	:	Proceq Resipod
Serial Number	:	RP01-005-0041
Measurement Mode	:	Surface
Contact Spacing	:	50mm
Specimen Shape	:	Rough surface
Minimum Measurement	:	324.0 kΩcm
Maximum Measurement	:	730.0 kΩcm
Mean Value	:	494.3 kΩcm



Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.

A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	-	Negligible risk of corrosion
When 50 to 100 kΩcm	-	Low risk of corrosion
When 10 to 50 kΩcm	-	Moderate risk of corrosion
When ≤ 10 kΩcm	-	High risk of corrosion

Based on the resistivity measurements for this location, there is a negligible risk of corrosion.

Authorised By:

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories

Issue Date: 10th July 2017